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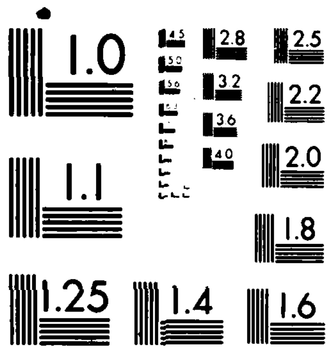

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COMPUTER-CONTROLLED IMAGE ANALYSIS OF SOLID PROPELLANT COMBUSTION HOLOGRAMS USING A QUANTIMET 720 AND A PDP-11

by

Marvin Philip Shook

September, 1985

Thesis Advisor: John P. Powers

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Computer-Controlled Image Analysis of Solid Propellant Combustion Holograms Using a Quantimet 720 and a PDP-11

by

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Lieutenant, United States Coast Guard
B.S., United States Coast Guard Academy, 1979

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN ELECTRICAL ENGINEERING

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ABSTRACT

This thesis describes the implementation of a computer-controlled image analyzer to obtain particle size information from holograms of rocket engine combustion products. The two machines utilized were a Quantimet 720 Image Analyser and a DEC PDP-11 digital computer. The machines are described in terms or their hardware, software, and interface. Preliminary results have been included and indicate that the present system is incapable of obtaining the desired particle information from a hologram. The causes for this, as well as their resolution are discussed.

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LIST OF ABBREVIATIONS

ACP	Anticoincidence Point
CIF	Control Interface
DEC	Digital Equipment Corporation
DMA	Direct Memory Access
DSD	Data Systems Design
FIFI	Field/Image/Feature Interface
MS3	MS3 Standard Analyser
NPS	Naval Postgraduate School
PLI	Plumbicon Light Integration
TDS	Technical Data Sheet
VFS	Variable Frame and Scale

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I. INTRODUCTION

This effort was undertaken as one part of an on-going research project at the Naval Postgraduate School (NPS) that is concerned with investigating the effects of adding metal particles to rocket fuel for the purpose of improving engine performance. To more accurately model the combustion process of the added metal particles and predict their affect on engine performance, the particle size distribution as a function of axial position in the engine during the burn cycle is needed. This data is essential to the study of particle additives, but it is difficult to obtain.

Presently, different approaches are being explored to obtain this information. These include using high speed motion pictures, scanning electron microscope analysis, scattered laser light measurement of volume-to-surface mean diameter (D32), and holograms. [Ref. 1]

The technique that is being evaluated in this thesis is analysis of the holograms. A hologram of the combustion products is made during the burn cycle and is later reconstructed for analysis with the Quantimet 720 Image Analyser. Glass windows in the rocket's walls allow recording the hologram during the burn. A one joule, 50 nanosecond pulse from a ruby laser is used to produce the hologram. This laser operates at a wavelength of 694.3

nanometers and has a 3.2 centimeter beamwidth. In order to reconstruct the hologram, the developed hologram plate is positioned inside a holocamera box, (Figure 1.1), which is mounted on top of a motorized XYZ stage. The reconstruction laser beam impinges the glass plate at an angle of 60 degrees and projects the reconstructed image outside the box for viewing by the microscope and subsequent analysis. A one-half watt krypton-argon laser operating at a wavelength of 647.1 nanometers is used as the reconstruction laser. It was selected to approximate the recording laser's operating wavelength to minimize distortions during reconstruction. The use of the motorized XYZ stage exploits the 3-D characteristics of the hologram and permits positioning the image by remote control.

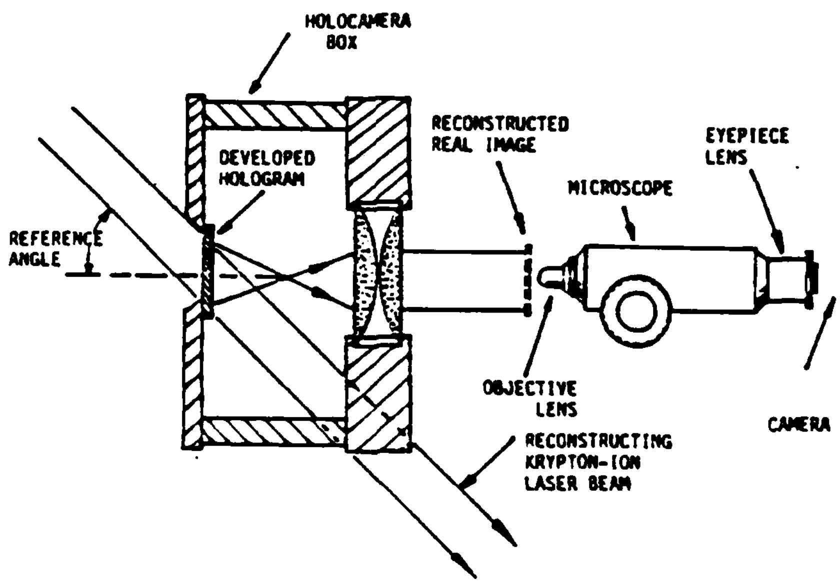


Figure 1.1 Hologram Reconstruction
[Ref. 2, Figure 3.2]

Previous work at NPS, [Ref. 2], was devoted to installing the Quantimet and investigating its capabilities for acquiring the desired particle size distribution from the hologram. During this previous effort, considerable obstacles were encountered while using the Quantimet to analyze the holograms. These were primarily concerned with the quality of the holographic image. The Quantimet performs measurements based on gray levels where objects are distinguished from the background by a distinct change in gray level. This requires an image with sufficient contrast and resolution. The dominant problems with the holograms are the speckle pattern throughout the image, and inadequate and uneven brightness of the image, which are aggravated by the presence of smoke. These are described in detail in References 1, 2, and 3. The affect of these problems was magnified by being limited to using the Quantimet in manual mode.

As a continuation of the previous work, the objective of this thesis was to implement computer control of the Quantimet in order to investigate the capabilities of this mode to overcome the difficulties involved with analyzing the holograms. This required interfacing the image analyzer with a digital computer and then developing procedures for analyzing the image data. Establishing a reliable interface between the two machines became a major obstacle in this effort, and consequently consumed most of the time. Cnce the computer interface was established, work began on using the Quantimet in the computer-controlled mode to automatically obtain particle size distributions. Good results were obtained when a clean, sharp image was used with adequate illumination, contrast, and resolution. However, the problems inherent with the holographic images remain to be substantial.

The remainder of this thesis is divided into six chapters. Chapter II describes the Quantimet 720, its modules and their capabilities, and Chapter III describes the computer system. Chapter IV contains a description of the problems encountered in implementing the interface between the two machines; and Chapter V contains procedures for using the Quantimet in the computer-controlled mode. The information contained in these chapters applies to the system as used at NPS. Additional information for the Quantimet can be found in References 4, 5, and 6; and for the computer in References 7, 8, and 9. Chapter VI contains results obtained from using the system to analyze a calibration standard reticle. Chapter VII contains concluding remarks.

II. THE NPS QUANTIMET 720 SYSTEM 23

The Quantimet 720 Series 20 System 23 is a modular, high-resolution, television-type image analyzing system capable of being computer-controlled to perform a wide variety of image analysis tasks. Its modules are designed to permit different configurations so that the system's capabilities may be adapted to meet the specific needs of a particular imaging problem.

The System 23 is supplied with software in the form of a Standard Routine and Macro assembly language routines. The Standard Routine performs measurements tasks by interpreting the keys of a computer keyboard as image analysis instructions. The Macro routines are the same as those used in the Standard Routine and may be combined into libraries suitable for a system's particular configuration and then linked to FORTRAN or BASIC programs.

The NPS System 23 contains twelve modules and can make a number of measurements according to gray levels, sizes, and shapes; and simultaneously display the results. It can also be computer-controlled and can digitize the video image for transfer and storage. The following sections describe the measurement process, the modules, and the software.

A. FRAMES

The Quantimet 720 provides displays and measurements on the basis of frames. The two categories of frames are physical and measurement. There are six physical frames which are labeled scan, video, big, small, variable, and smashed; these are portrayed in Figure 2.1. The scan frame is the actual area of the camera's scanning field; however, some of this frame is lost during the process of establishing the others, so the displayed video image is as defined by the video frame. The big frame and small frame are standard-sized frame areas within the video frame and are used to determine the detection and measurement regions.

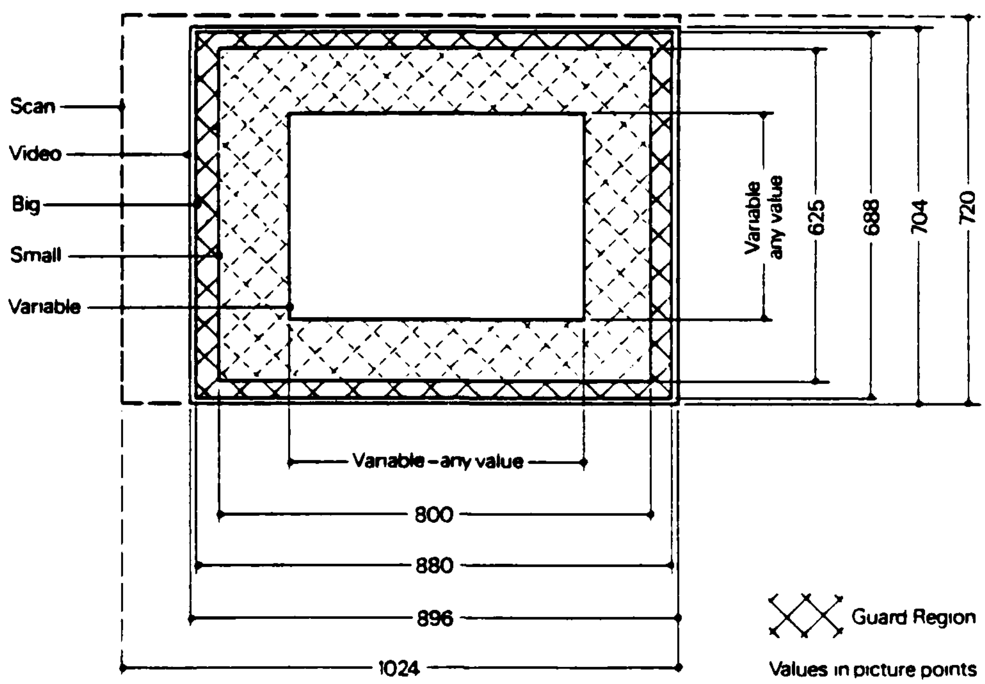


Figure 2.1 Quantimet 720 Frames
[Ref. 4, Figure 6.1]

The smashed frame and variable frame are derived from the standard size frames and provide a detection area consisting of adjustable width horizontal strips and a measurement region that may be any position or size within the detection area.

The physical frames are combined to provide two measurement frames: blank frame and live frame. The blank frame area is used to define the detected image; and the live frame area is used to perform measurements and provide the computed image display. The area in between the blank frame and live frame is called the guard region and is used as a buffer zone to prevent counting features twice when the image is moved.

In the NPS system the blank frame is derived from the big frame; and the live frame may be switched between the small frame and he variable frame.

B. MEASUREMENTS

The Quantimet 720 is designed to perform geometric or densitometric measurements that can be either field- or feature-specific. The source of data for all measurements is the detected image.

The present application is concerned only with geometric measurements. Field-specific and feature-specific measurements are distinguished in the following way. Field data is obtained from all detected picture points inside the live frame area. Feature-specific data is obtained from all detected picture points for those individual objects that have their anticoincidence point (ACP) inside the live frame. An object's ACP is defined as the point just to the right of the object's lowest projection, on the first scan line below the object. This is illustrated in Figure 2.2.

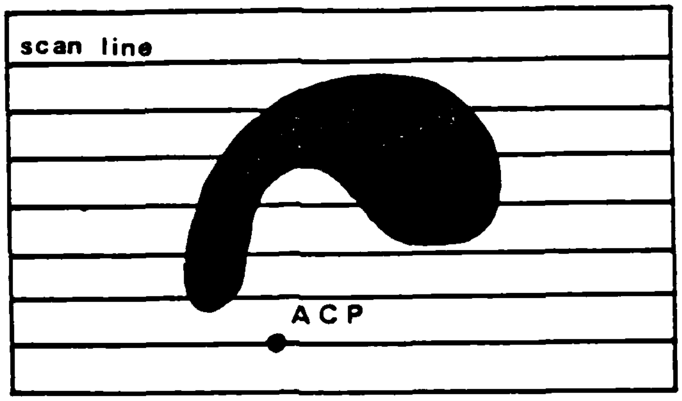


Figure 2.2 Anticoincidence Point
[Ref. 4, p. 14.9]

Objects with their ACP inside the live frame are called features. Figure 2.3 illustrates the differences between field- and feature-specific measurements.

1. Field-specific Measurements

The field data measurements available on the Quantimet are area, perimeter, intercept, and count. Only area and count are relevant to the present application. The field measurement of area consists of all detected picture points within the live frame; and the count measurement is the number of features inside the live frame. These are illustrated in Figure 2.4.

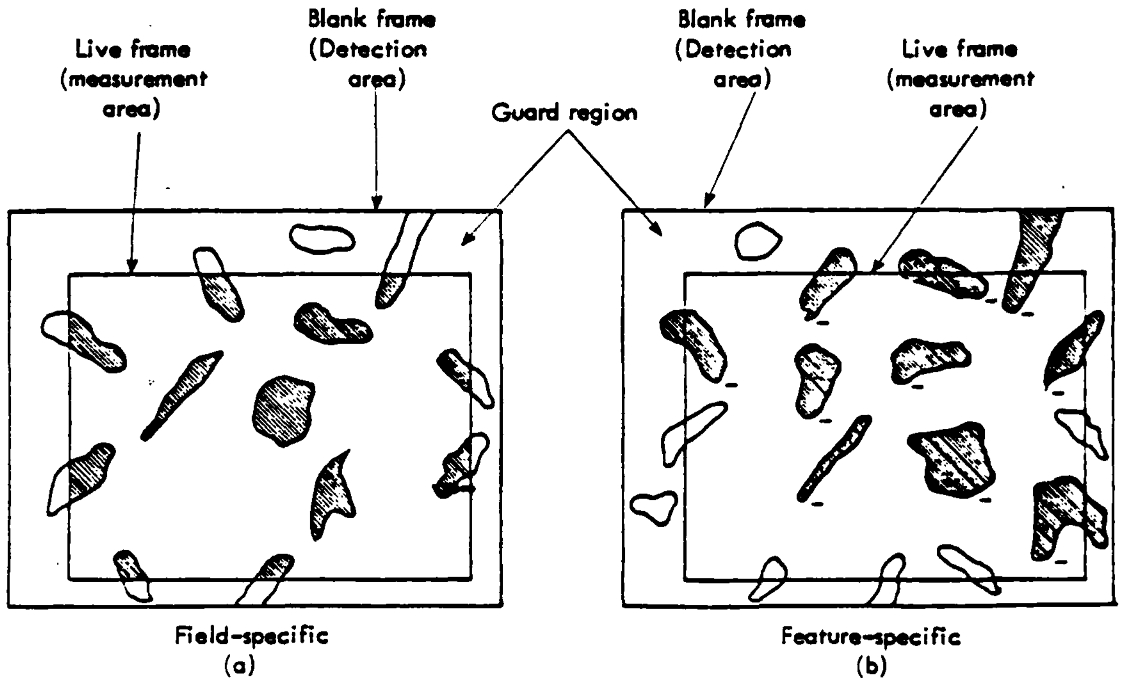


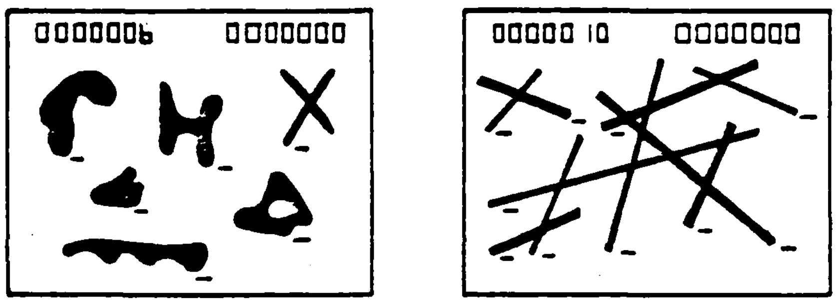
Figure 2.3 Comparison of Field and Feature Data
[Ref. 5, Figure 1.5]

(a) Area

(b) Count

Figure 2.4 Geometric Field Measurements
[Ref. 5, Figure 6.3]

The count measurement may be defined in a variety of ways. The ones germane to particle sizing are End Count and Full Feature Count. As depicted in Figure 2.5, the Full Feature Count identifies all contiguous objects as a single feature, whereas the End Count measurement can identify overlapped particles if they are oriented so that there are multiple downward projections. In the present application, where particle overlap is frequent, the attributes of End Count are utilized to obtain more accurate size distributions. (See Figures 6.4 and 6.5.)



Full Feature Count (a) End Count (b)

Figure 2.5 Full Feature Count and End Count Measurements [Ref. 5, Figure 6.1]

2. Feature-specific Measurements

The following feature measurements are provided by the Quantimet: area, perimeter, horizontal and vertical projections, and feret diameters at angles of 0, 45, 90, and 135 degrees relative to the horizontal scan lines. These are illustrated in Figure 2.6. The pertinent ones are area and feret diameter. The area measurement comprises the number of detected picture points for all features in the live frame; and the feret diameter measurement contains the sum total of feret diameters for all features.

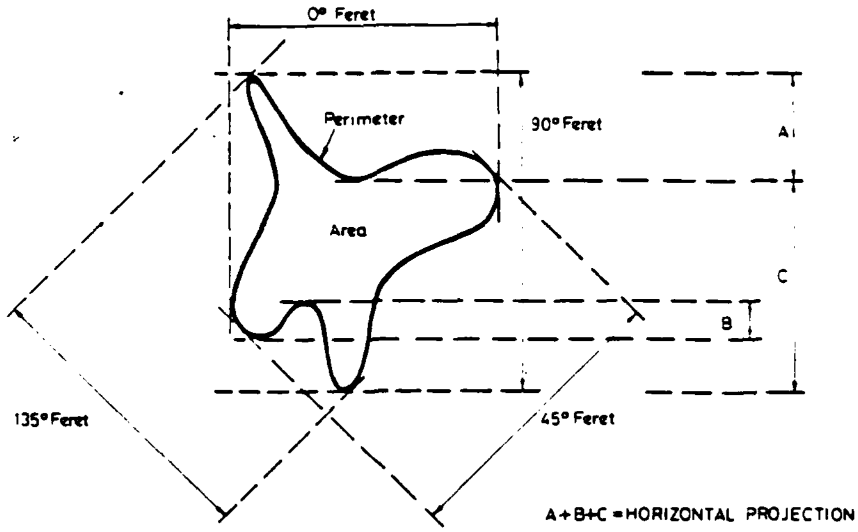


Figure 2.6 Geometric Feature Measurements
[Ref. 10, p. 4]

3. Sizing Criteria

The field and feature measurements can be subjected to two kinds of sizing criteria, which are applied sequentially.

The first sizing logic applied to the data is called chord sizing. An object's chord size is defined as the number of its detected picture points along a scan line, i.e., an object is composed of parallel horizontal chords. This logic is usually employed to reject objects that have a maximum chord length that is shorter than the sizer setting.

For example, in Figure 2.7 only the object with chord length greater than 'ℓ' is used in the measurement process. Chord sizing logic is useful to obtain particle size distributions as a function of the features' maximum chord lengths, and to reject small spurious features that are produced by noise.

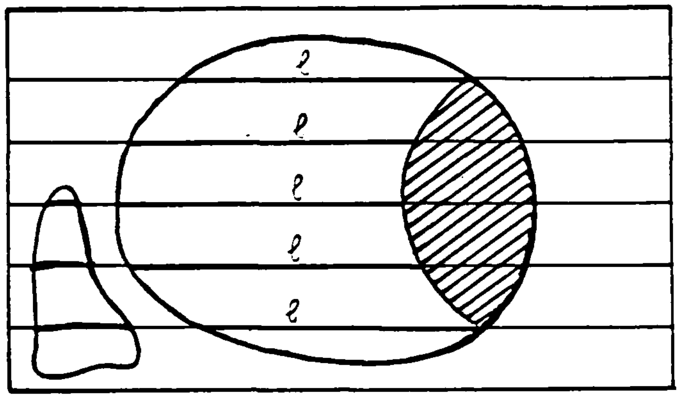


Figure 2.7 Chord Sizing
[Ref. 4, p. 14.9]

The second kind of sizing logic is referred to as classifier sizing and it uses the selected measurement parameter as the basis for accepting features. This criteria selects only those features that possess the specified parameter size, e.g., area greater than fifty. This sizing logic has an upper and a lower limit setting so it can be applied as greater than, less than, or in between the settings.

4. Pattern Recognition

Pattern recognition involves selecting or eliminating features on the basis of a measurement parameter or a combination of parameters. The Quantimet 720 can be provided with a Form Separator module that identifies features on the basis of the relation $(A \times B)/C^n$, which is called a form factor. A, B and C may be any measured parameter and 'n' may be 1, 2, or 3. The NPS System does not contain this module, but the System 23 software can accomplish the same result.

C. MODULE DESCRIPTIONS

The twelve modules constituting the NPS System 23 are listed below:

System Control	Function Computer
Display	Classifier-Collector
Plumbicon Scanner	Variable Frame and Scale
1D Auto Detector	MK1 Frame Smasher
Light Pen	Control Interface
MS3 Standard Analyser	Field/Image/Feature Interface

These modules are linked together by three categories of connections that are called standard rear connections, high level programming connections, and programmer control connections.

The standard rear connections provide basic timing and logic signals between the modules. These are usually required connections for a group of modules.

The high level programming connections are installation or task dependent, e.g., these connections determine the blank and live frames and the placement of the Light Pen in the data path.

The programmer connections provide for computer control of the modules by the Control Interface module. This module was preceded by the Programmer module, which is no longer supported by the manufacturer.

The detailed list of all connections used in the NPS system is contained in Appendix F.

The system has two fundamental modes of operation: manual and computer-controlled. The capabilities of each of these modes depend on the particular configuration of modules.

A minimum system, which is depicted in Figure 2.8, consists of the scanner, system control, detector, and display modules; and is essential to all configurations.

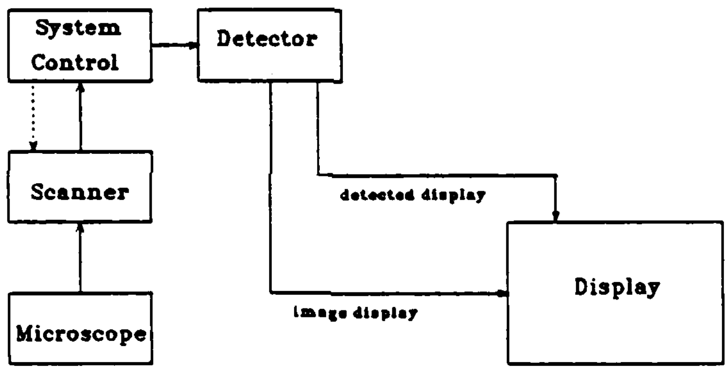


Figure 2.8 A Minimum System 23

The scanner, directed by System Control, is coupled to the microscope to perform the vital function of converting the optical image into the video signal for use in the detector. The detector provides the analog image display and the detected image display. All measurements are made from the detected image for all configurations. The only measurements produced by the minimum system are area and intercept.

The pattern recognition modules shown in Figure 2.9 are added to obtain information on the basis of individual features within the detected display. These modules include the MS3 Standard Analyser, Function Computer and Classifier-Collector. Also the Light Pen may be used to manually select features of interest. In this configuration the detected data is passed on to the Light Pen which can be used to select features of interest, or if the pen is left in its holder all data is passed on for measurement. The MS3 subjects the detected data to chord sizing and provides field data that is passed on to the Function Computer and Classifier-Collector. It also acts as the first module in the computed display daisy chain. The Function Computer serves as the source of feature data and passes it on to the Classifier-Collector and the computed display. The Classifier-Collector module subjects the feature data to classifier sizing, and collects all field and feature data for input into the computed display.

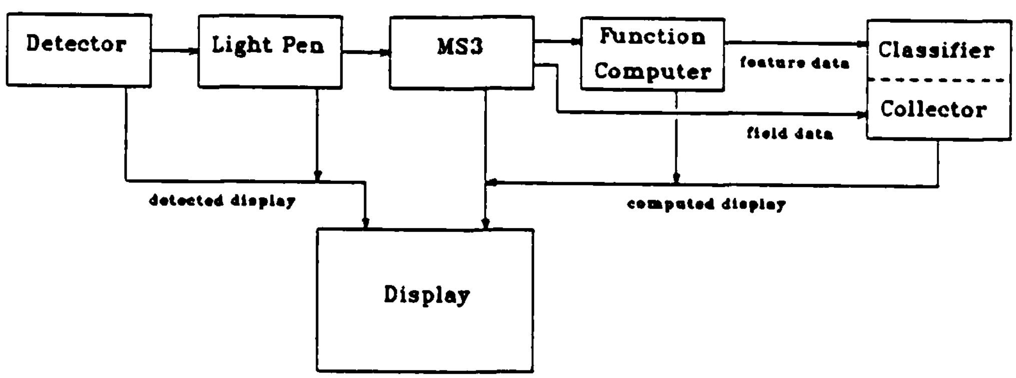


Figure 2.9 System 23 with Pattern Recognition Modules

Additional measurement capabilities are obtained by selecting only portions of the measurement frames. This is accomplished by including the MK1 Frame Smasher and the Variable Frame and Scale (VFS) modules as indicated in Figure 2.10. The Frame Smasher allows using the smashed frame to define the detector's blank frame; and, the VFS module provides the MS3 with a variable live frame and an 'X' and 'Y' scale for display within the live frame.

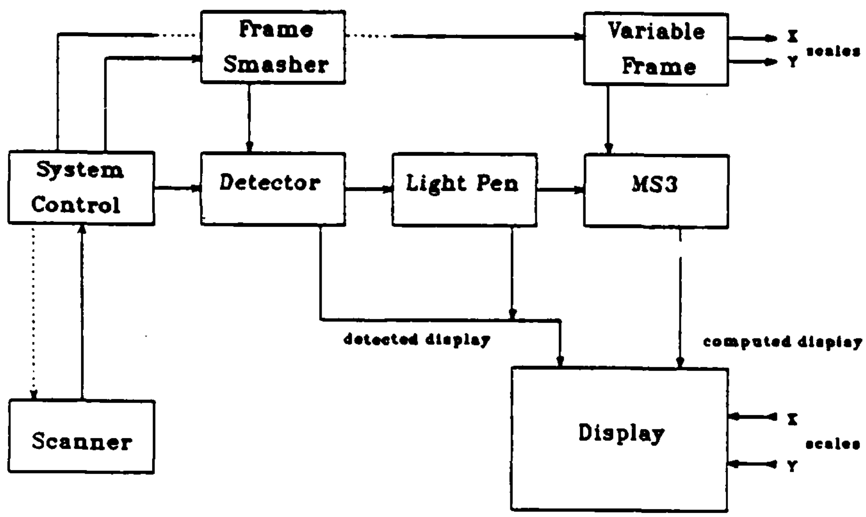


Figure 2.10 System 23 with Frame Modules

Computer control and image transfer are achieved by including the Field/Image/Feature Interface (FIFI) and Control Interface (CIF) modules as shown in Figure 2.11. The CIF transfers program-controlled module function commands; and, the FIFI receives field and feature data from the Collector, digitized image data from the detector, and sends display data to be included in the computed display.

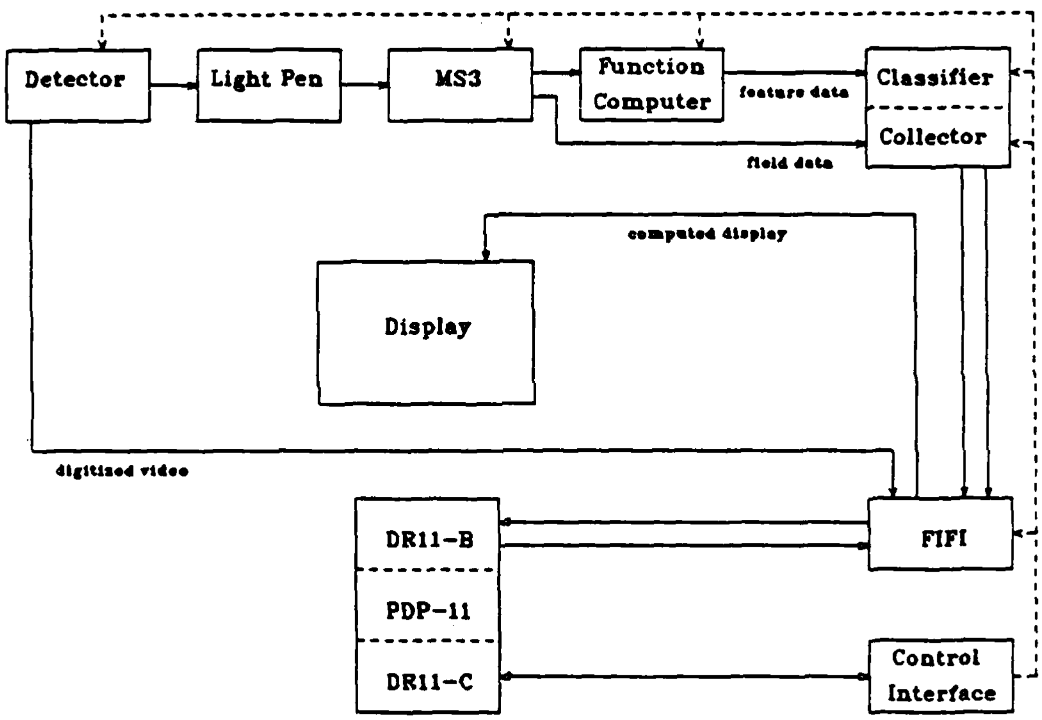


Figure 2.11 System 23 with Computer Interface Modules

Figure 2.12 is a composite block diagram of the Quantimet modules as configured in the NPS system. A more detailed description of the modules follows.

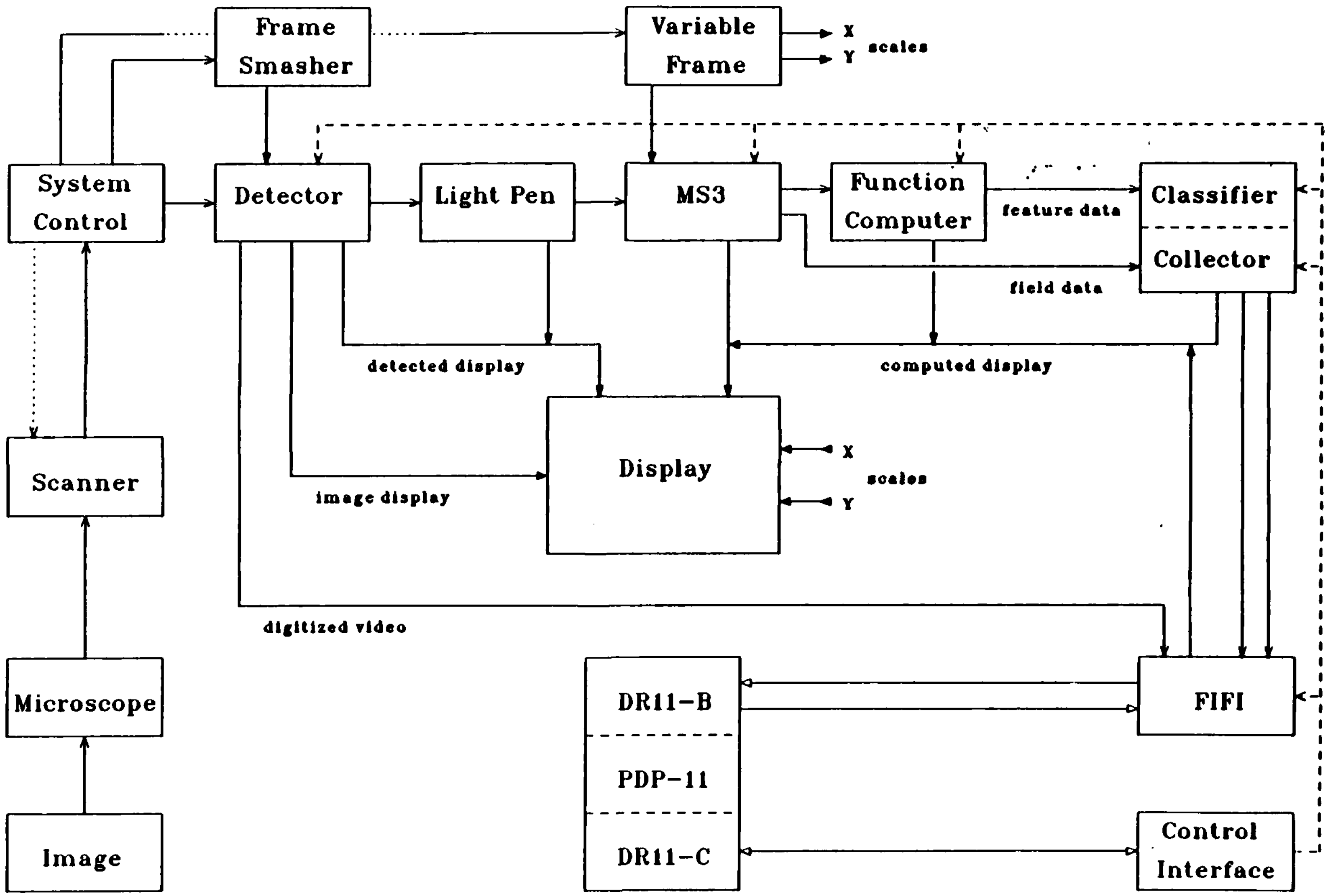


Figure 2.12 Block Diagram of the NPS System 23

1. System Control

This module provides the system's timing, controls the scanner, accumulates and provides for display of measurement results, and compensates for shading in the scanner image. An 8 megahertz clock is used to synchronize the modules and to provide a 720-line frame repetition rate of 10.8 frames per second. At this speed, measurements can be obtained at a rate of about one per second. The clock is also routed to other modules to compensate for delays introduced by them in the data chain. For low light level situations the light integration for the Plumbicon Scanner may be increased from one frame scan to five or twenty-five frame scans, with a subsequent reduction in the measurement scan rate. Also an averaging facility may be used to average the results over sixteen measurement scans.

An internal accumulator register provides a seven decimal digit result for displaying in the upper left corner of the screen. This register may be switched to provide a single result for each measurement scan or to accumulate results over many scans. System Control also accepts input from an external register to display in the upper right corner of the screen. The present configuration does not have an external accumulator so the right seven digit display is always zero.

The shading corrector compensates for inconsistent gray levels as a function of position in the frame due to uneven illumination of the specimen or uneven sensitivity in the scanner face.

2. Display

This module provides a 15 inch screen for the following displays:

- Analog video image from the detector,
- Detected image from the detector,
- Computed display from the pattern recognition and FIFI modules,
- 'X' and 'Y' graticules from the variable scale,
- Two seven digit results' displays, and a
- Guard region between the live and blank frames

A connection is also provided for an external display. The displayed video image is 704 lines of 896 picture points equally spaced in the horizontal and vertical directions. The detected image is displayed inside the blank frame and the computed image is displayed inside the live frame. Each display may be turned on and its contrast adjusted independent of the others. The displayed images are not used to perform any measurements directly; however, proper contrast levels for the video image and detected display are important when manually setting the detector thresholds.

3. Plumbicon Scanner

The scanner converts the optical image into the analog video image for use in the detector module. The Plumbicon Scanner is specifically designed for the Quantimet 720. It differs from conventional television scanners by using a slow 720 line scan with no interlacing. This provides a higher signal to noise ratio which gives better resolution and accuracy for stationary images. It has a peak spectral response for light at the 500 nanometer wavelength (green) and has a 22 millimeter field of view compared to the conventional 18 millimeter.

4. <u>1D Auto Detector</u>

This module receives the analog video from the scanner via System Control and provides the binary level detected image that is used for all System 23 measurements. It also digitizes the analog scanner image into sixty-four levels for transfer to a digital computer via the FIFI module. The primary purpose of this module is to provide for detection of objects by using two separate 64-level thresholds ranging from a black level of 0 to a white level of 63 with a one-half level offset to allow for continuous selection of the detection threshold. These thresholds may be selected automatically by the detector, remotely via the Control Interface, or manually. The detection logic may be switched to provide for darker than, lighter than, or between (slice mode) the threshold selector settings.

The detector module's designation, (1D Auto), represents its salient characteristic: It compensates for the non-ideal response of the scanner video to a sharp transition in brightness level by a process called autodelineation. This process effectively sharpens the video image so that the detected image is the same size as the original. As illustrated in Figure 2.13, the scanner's video response (curve 'D') to a sharp transition in gray level is characterized by gradual slopes on its leading and trailing edges. This phenomenon smears the edges of the object and impedes proper selection of the detection threshold (line 'C'). An incorrect threshold will cause the detected image to be larger or smaller than the original image (lines 'A' and 'B', respectively). The auto-delineation process automatically enhances the video signal about the 50 percent point change in gray level and produces curve 'E' and a correctly-sized detected video signal.

This correction is only provided in the horizontal direction, (1D: one dimension), so a correctly detected circular object appears to have its top and bottom flattened, (see Fig. A.1).

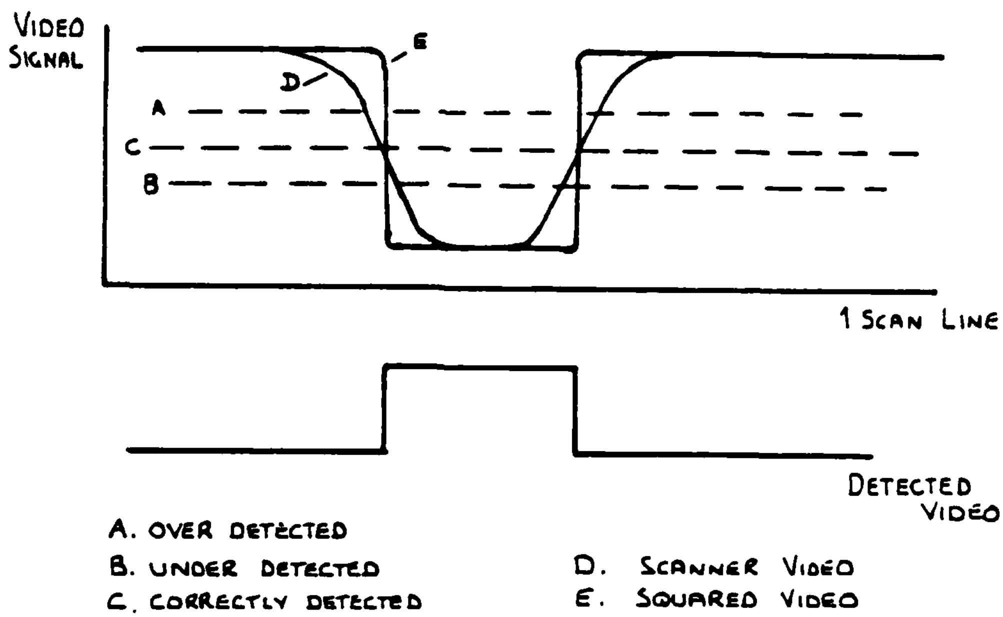


Figure 2.13 Autodelineation [Ref. 5, Figure 5.8]

5. Light Pen

The Light Pen allows an operator to manually select individual objects of interest for measurement. It may be used in one of two ways depending on its high level programming connections. First, it may be used to define the detector's blank frame; this method is called gated blank frame. The second way, which is the one used in the NPS system, is to use the Light Pen to select individual features for measurement by the Function Computer and Classifier-Collector via the Number 2 Key on the MS3 Standard Analyser. Appendix B contains detailed procedures for using the Light Pen.

6. MS3 Standard Analyser

This module receives the detected image as input and subjects it to chord sizing logic. It then performs a field measurement task in the normal mode or it may be used in the pattern recognition mode to pass information to the Function Computer for feature-specific measurements, subject to the Light Pen selection logic. Features passing the MS3 chord sizing logic are identified by a small rectangular 'flag' at their ACP on the computed display, (see Fig. 2.3).

7. Function Computer

This module operates under control of the MS3 Standard Analyser in the pattern recognition mode and performs feature-specific measurements on the detected image that was subjected to the MS3 chord sizing logic and Light

Pen selection logic. The measurements for all features are performed within a single measurement scan. Displays of the measured parameter may be viewed on the computed display via the module's display push button.

8. Classifier-Collector

The Classifier and Collector modules are combined into one unit with the Classifier's controls and connections on the top and the Collector's on the bottom.

The Classifier receives measurement data from the Function Computer and then subjects the results to sizing logic. These results are then passed onto the Collector. Features passing the Classifier sizing logic are flagged on the computed display under control of the module's display switch.

The Collector receives data for those features passing the MS3 chord sizing logic and the Classifier sizing logic and releases the computed measurement for these features. The Collector also has the capability of selecting feature-specific measurements from a different Function Computer and also using the output from a Form Separator module. However, neither of these is available in the NPS System. In the NPS System the Collector serves only to transfer field and feature measurements to the FIFI module. Features selected by the Collector may also be flagged using the Collector display switch.

9. Variable Frame and Scale

This module provides a variable sized frame using one of the standard frames from system control, and vertical and horizontal graticules for display within the live frame area. The NPS system uses the standard small frame as the input to this module. The output is then used as the measurement live frame. This module is used to define the appropriate size for the guard region between the blank and live frame and to determine the calibration factor for converting picture point size to physical unit size.

10. MK1 Frame Smasher

This module, which serves no significant purpose for the present application, is capable of dividing an input frame into variable width on/off horizontal strips. The blank frame is used as input for this module in the NPS System. The on/off strips allow for quantizing an object into a set of unique features, each of which is a horizontal strip. (See Figure 2.14.) One application of this is storing image data as a set of horizontal chords and then later using the FIFI marker display facility to re-display the image.

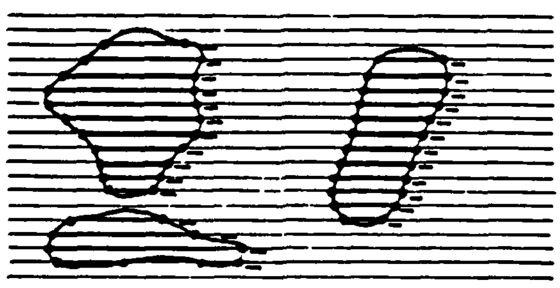


Figure 2.14 Quantization of Objects by Frame Smashing
[Ref. 5, Figure 7.6]

D. SYSTEM 23C INTERFACE MODULES

The System 23 image analyzers consist of three groups: the 23A, the 23B, and the 23C. They are designed to be computer-controlled by a DEC PDP-11 running the RT-11 operating system. The significant difference between the three systems is that the System 23C uses a Control Interface module while the 23A and 23B use a Mini Control Interface module. The NPS System is a small version of the 23C. The standard System 23C contains additional modules.

The Quantimet 720 System 23C accomplishes its interface with the computer through the Control Interface Module and Field/Image/Feature Interface Module. On the NPS System 23 these provide for computer-controlled operation of all image measurement tasks except for focusing the image, moving the image, and selecting the size and position of the live frame. The former two may be performed remotely via the Newport Automatic Stage Controller. In addition to the measurement tasks the System 23C can transfer the digitized video image to the computer for digital image processing.

1. Control Interface (CIF)

The CIF provides for computer-controlled module switching and sizing limit setting for the Quantimet 720 modules. It also determines the beginning of the measurement scan . The CIF, when used in a standard System 23C, transfers instructions to modules on twenty-five channels designated A through Y.

In the NPS system only a portion of the CIF connections are made. These are listed below in Table II.1.

TABLE II.1 CONTROL INTERFACE CHANNELS

Channel	Module
AA	Detector Threshold Selection
AB	
AC	MS3 Function Selection
AD	
AE	Collector Function Selection
AF	FIFI Function Selection
AG	Function Computer Function Selection via FIFI
AH	
AI	Detector Threshold Selection
AJ	
AK	Detector Threshold Selection
AL	
AM	
AN	
AO	
AP	MS3 Chord Sizing
AQ	Classifier Sizing
AR	
AS	
AT	
AU	
AV	Control Bus Reset
AW	Classifier Sizing
AX	
AY	Synchronize Transfers

The module switching instructions are transferred on fourteen channels: A thru N. These channels use an octal code to define a module's function. The octal code corresponds to the weighted sum of selected bits in the 6-way CIF connections. The 6-way connections are labeled 1,2,4,8,16, and 32 corresponding to a radix 2 convention. These are represented in the software as octal 1,2,4,10,20, and 40. Some modules use only the four center bits of the code and the function selected corresponds to the pictorial programmer code on the front panel of the module. As indicated in Figure 2.15, to select the vertical feret function an octal 34 is transferred over the control bus. The codes for all modules are contained in Appendix B of Reference 6.

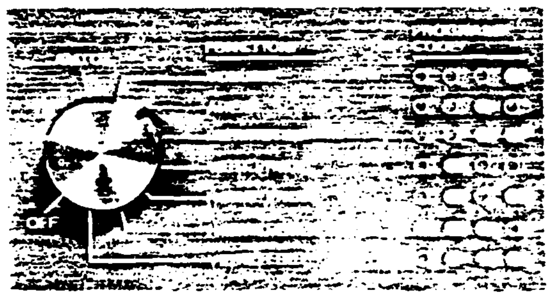


Figure 2.15 Programmer Code for Function Computer
[Ref. 4, TDS 7223/2]

The sizing limits are transferred on six 32-way channels, O thru T, using the same numeric representation as used on the modules' thumbwheels. Channels U thru Y are used for single bit controls.

The beginning of a measurement scan is initiated by use of the "auto" signal, which is routed through FIFI to System Control in the NPS system.

The following is a summary of the functions capable of being selected by the Control Interface for each of the NPS System modules.

a. System Control

CIF is wired to initiate the measurement scan.

b. Display

None.

c. Plumbicon Scanner

None.

d. 1D Auto Detector

The CIF is used to transfer threshold selection commands to the detector. As seen in Table II.1, three channels; A, I and K, are used for selecting the thresholds. These channels are used as indicated below:

Channel A: All six bits are used to hold the threshold value.

Channel I Bit 2: Load Selector A
Bit 4: Load Selector B
Bit 10: 6-Bit mode (active low)

Channel K Bit 40: Keyboard - Selects detector's internal standard (active low).

Channel A holds the desired threshold value ranging from 0 to 63 in an octal format of 0 to 77. The decimal value can be viewed on the CIF display by selecting switch position A. Channel I is used to select the mode of threshold selection and which threshold to set. The mode may be either 6-Bit or not, and the threshold may be either A or B. Channel K is used to call the 1D Detector's automatic internal threshold for field or specimen standard detection levels.

e. Light Pen

The Light Pen may be wired to initiate the measurement scan if the CIF is not used in the system.

f. MS3 Standard Analyser

The CIF can be used to select the measurement mode, input video, and chord sizing value. The measurement modes are normal and pattern recognition. If the normal measurement mode is selected, then one of the four field measurement functions may be selected. The input video may be either normal or modified.

g. Function Computer

The CIF transfers the measurement function selection corresponding to the programmer code on the module's front panel. This is transferred via the software codes connections on the FIFI module. This technique is useful to identify which Function Computer made the measurement when more than one is in the system. There is no obvious benefit from this in the NPS system.

The volume function, which is a densitometric measurement, may be selected by the CIF; but, the NPS Function Computer does not contain the necessary components to accomplish the result.

h. Classifier-Collector

The CIF transfers function selection to the Collector. Valid functions in the NPS system are Function 1, which is wired to the Function Computer, and Count. Two channels are used for setting the Classifier's lower sizing value. Channel Q holds the value of the sizing and channel W is used to load it into the Classifier.

i. Variable Frame and Scale

None.

j. Frame Smasher

None.

k. FIFI

The CIF transfers mode selection to the FIFI module according to the programmer code on the module's front panel.

2. <u>Field/Image/Feature Interface (FIFI)</u>

The FIFI module provides the high speed interface for transferring measurement and image data to the computer using direct memory access (DMA). It also allows the computer to transfer data to the Quantimet display. The FIFI has four types of data transfer. These are field data transfer, feature data transfer, image data transfer, and display data transfer.

All data transferred from FIFI to the computer is preceded by a header block that consists of ten 16-bit words. The header contains information that identifies the type of measurement, the number of Function Computers used (always one in the NPS System), the software code used, and the FIFI's thumbwheel positions. The header was developed primarily for use with magnetic tape storage and is not pertinent to the NPS system.

a. Field Data Transfer

Field data is routed to FIFI through the Classifier-Collector module. It consists of the measurement type and the result. This measurement value is transferred to the computer in two words following the header data.

b. Feature Data Transfer

Feature data is also routed to FIFI through the Classifier-Collector module. The content of the transferred data depends on the position of the transfer mode switch on the rear panel. The switch determines if only the feature measurement data, or only the feature location, or both measurement and location data are transferred. The latter is the setting in the NPS system. Feature data is transferred following the header in four-word blocks, one block per feature. In each block the first two words contain the feature ACP location; the second two words contain the measurement value.

c. Image Data Transfer

Image data is routed to FIFI from the 1D Auto Detector. The detector module digitizes the image to give a 6-bit, sixty-four gray level representation for each picture point in the blank frame. The FIFI module adds two more bits of information to each picture point: one bit to indicate if the picture point is inside the variable frame, and one bit to indicate if the picture point is part of the detected image. The image data bytes are transferred following the header and a four-word block containing the location of the top left and bottom right corners of the variable frame. One column of image data is transferred per measurement scan.

d. Display Data Transfer

The computer can transfer one of two kinds of data per scan for displaying with the computed image display. These are alphanumeric data and marker data.

Marker data consists of variable length horizontal line segments and is transferred in a two-word block specifying the lines' left position and length.

Alphanumeric data consists of ASCII character strings. Allowable characters are ASCII 40 through 137 (octal). Each character is displayed in a 5 x 7 format inside an 8 x 16 picture point area. The string is transferred two characters per word and is preceded by two words containing the first character's location.

E. QUANTIMET SYSTEM 23 SOFTWARE

The System 23 software that is provided with the NPS system may be considered in three categories. These are the System 23 Standard Routine files, Quantimet Link Version 4.1 files, and image transfer demonstration program files.

1. System 23 Standard Routine Files

The System 23 Standard Routine software consists of the following three files: Q.SAV, CONFIG.SAV and Q2DAT.CAL.

The Q.SAV file is the Standard Routine. It is a stand-alone, interactive, executable program that interprets keyboard key strokes as measurement instructions. It is capable of performing all the Quantimet measurements, but not image transfer. It allows for creating and storing unique routines for accomplishing a particular measurement task and its capabilities may be supplemented by chaining to other user-developed programs. This allows one to perform image transfer operations while using the Standard Routine. The chaining operation is an RT-11 operating system feature and was not used in this effort. The program is supported by two manuals, [Refs. 11 and 12], that provide a description of the routine and instructions for performing the measurement tasks. Details for using the Standard Routine in the NPS system are contained in Section V.B.

The CONFIG.SAV program is an interactive program used to define the configuration of the system and default calibration values used by the Standard Routine. It conveys the calibration information to the Standard Routine by producing the file Q2DAT.CAL, which is read by the Standard Routine. No description of the program is provided in the manufacturer's documentation, [Ref. 13]; but, when the program is run, a Help option is offered that describes the purpose of the Routine. Other options offered are Summary and Alter. The Summary option provides the present status of all settings and the Alter option allows changes to be made to the settings. Details of these options and the present configuration status are included in Appendix D.

2. QLINK V4.1 Files

These files, which are not required in order to use the Standard Routine, are provided as a supplement to the standard System 23 software. They include the assembly language routines necessary to accomplish the Quantimet 720 image analysis operations, and test programs to isolate faults in the interface modules.

a. Source Programs

Sixty-two Macro assembly language routines are provided for use with user developed programs. Instructions for using the source routines are included in two manuals: one for BASIC and one for FORTRAN applications, [Ref. 6]. User developed programs may be written to perform in a stand alone manner or to be chained to the Standard Routine. Only stand alone FORTRAN programs were considered in this effort.

The assembly language routines are linked to the calling FORTRAN program in the form of libraries. The four standard libraries that are provided with the QLINK files are listed and described below:

QLIBDC.OBJ - applicable to NPS
QLIBDN.OBJ
QLNBDC.OBJ - applicable to NPS
QLNBDN.OBJ

By using the following criteria, the appropriate library is chosen according to the particular System 23 configuration and the function being performed.

The third letter in the file name, either 'I' or 'N', indicates whether testing routines are included. If 'I' is used, the testing routines are included and are useful during program development to assist in isolating errors. Once the errors are resolved, the 'N' libraries may be used to provide faster execution and less storage requirements.

The sixth letter in the file name, either 'C' or 'N', designates whether a Control Interface or Mini Control Interface is used in the system, respectively. The NPS system contains the Control Interface module, therefore a 'C' library is used.

The QLIBDC library was used to develop test programs during the implementation of the computer interface and for linking with the demonstration programs.

Appendix C contains instructions for linking the libraries in the NPS system.

b. Control Interface Test Program

The CIF test program, TCIF2.SAV, is provided to check out the operation of the CIF module. The program is supported by a user's guide, [Ref. 14], that proved useful in resolving the problems encountered when implementing the computer interface. The program consists of four tasks designated Test 1 through Test 4.

Test 1 provides the means to directly transfer module setting and measurement scan instructions over the control bus to quickly ascertain the operational status of the CIF. It also includes commands for transferring data with the FIFI module; these proved especially useful in understanding the FIFI data transfer operations and finally resolving the computer interface problems. This is discussed further in Section IV.

Test 2 verifies that the interrupt vector for the DR11-C is correct, i.e., 300; (see Section III.B).

Test 3 determines what devices are connected to the DR11-C control bus. In the NPS system only the CIF is connected to the DR11-C and its address designation is 'A'. Recall that all the CIF channels listed in Table II.1 were preceded with the letter 'A'. Other Quantimets may have additional devices connected to the DR11-C control bus, such as an X-Y stage controller; these would be assigned to other addresses.

Test 4 determines the state of the CIF extended busy signal. This signal is only relevant to systems with input peripherals under computer control, (such as an X-Y stage or Auto Focus), and serves to delay measurements until the peripheral is in position. This is not applicable to the NPS system, and the correct status of the signal is uncertain. The program's response is always 'busy', but this has no apparent effect on the system.

c. FIFI Test Program

This program, FTEST.SAV, is used to check out the operation of the FIFI module. Five documents are available with the NPS system to support this program: [Refs. 15,16,17,18, and 19]. These manuals are difficult to use because they contain a lot of information that is inapplicable to the NPS system, and at times all four must be used to ascertain the proper test procedure. Consequently, running FTEST is very complicated.

The program contains ten tests that may be operated with or without the CIF module. Only seven of these may be performed on the NPS system; the other three require special test apparatus that is not available. The seven tests applicable to the NPS system are listed below:

Test 1	Function Selection Code Transfer
Test 2	Interrupt Handling
Test 3	Field Data Transfer
Test 4	Display Data Transfer
Test 5	Header Transfer
Test 6	Feature Data Transfer
Test 8	Image Data Transfer

Test 1 checks the function code that FIFI transfers to the DR11-B's status and command register to define the type of transfer that will be made (see Section III.C). These codes are output to the computer terminal corresponding to the FIFI modules switch position.

Test 2 checks for proper handling of interrupts between the FIFI and DR11-B. The response that indicates proper operation is nothing until the test is terminated by typing <control P>. The terminal will then receive the scan count. This count should reflect the time lapsed during the test, in seconds, multiplied by the frame repetition rate of 10.8 frames per second. Improper operation causes an error message to be output. These are described in detail in the references.

Test 3 verifies proper operation of field data transfer by checking that the number of words transferred is twelve and that the software code in the heading block is for field data. The field data is output to the terminal.

Test 4 is an extensive test that checks the operation of all FIFI operations. This is the only test that contains display data transfer exercises.

Test 5 checks for correct contents of the ten word header block. It checks the number of words transferred, verifies that the first word is minus one and then outputs the header data in decimal and binary form to the Quantimet display.

Test 6 pertains to feature data. It does not perform any checks, but provides a display of the feature's location and measurement value on the Quantimet Display.

Test 8 performs an image transfer operation of a 21 x 21 picture point area and allows for displaying or printing selected bits of the data.

3. Image Transfer Demonstration Programs

The following FORTRAN and BASIC programs are provided with the System 23 software:

(1) GRYIMG.FOR
(2) REDIMG.FOR
(3) DETIMG.FOR
(4) DENIMG.FOR
(5) FTRDEM.FOR
(6) QLDEM1.BAS
(7) QLDEM2.BAS
(8) QLDEM3.BAS
(9) QLDEM4.BAS

Of these only (1) thru (4) are mentioned in the documentation, [Ref. 12]. The FORTRAN programs were run in a stand-alone mode to determine the correct compiling and library linking process, and to observe the program results.

Programs (1),(2), and (3) output image data to the terminal in a two-dimensional format that resembles the displayed image. The GRYIMG.FOR program prints out the decimal gray level for each picture point inside the live frame. REDIMG.FOR prints out the gray level for each picture point also; but, in a character coded format. The DETIMG.FOR program prints out the detected image that is inside the live frame as 'X' for detected and 'blank space' for undetected.

The other two FORTRAN programs provide output on the Quantimet display. DENIMG.FOR gives a histogram of the gray levels contained inside the live frame. FTRDEM.FOR performs a feature measurement task and then labels each feature with its corresponding measurement ; e.g., area, at its ACP.

F. SUMMARY

The first of the two machines pertinent to this research has been presented in this chapter. The discussion has addressed the Quantimet's capabilities in terms of its measurement techniques, its hardware, and its software. The next step is to present the second machine, the computer, which is used to run the software and control the measurement process.

III. THE NPS PDP-11/04 COMPUTER SYSTEM

The NPS computer system consists of a DEC PDP-11/04 computer running the RT-11 operating system, a Qualogy DSD 880 Winchester hard disk and floppy disk for storage, and a DEC LA36 Decwriter terminal for entering and printing data. A DEC VT220 terminal may also be connected to the system, but it is not compatible with the System 23 Standard Routine.

A. PDP-11/04 COMPUTER COMPONENTS

The PDP-11/04 computer is a 16-bit word machine designed so that all components are connected to a single bus called the Unibus. The NPS computer system consists of the following modules which are connected to the bus on two backplanes, (a nine slot DD11-PK and a four slot DD11-CK), inside the BA11-K mounting box as illustrated in Figure 3.1.

1. Central Processor Unit (CPU)

The CPU used in the PDP-11/04 is the FD11-D mounted in a single module designated as M7263.

2. Memory

Two 16Kword MOS memory boards, each designated as MS11-SP, are mounted on two M7847 modules to provide 28K for program memory and 4K for input/output.

<table>
<tr><th colspan="6">ROW</th><th>SLOT</th></tr>
<tr><th>A</th><th>B</th><th>C</th><th>D</th><th>E</th><th>F</th><th></th></tr>
<tr><td colspan="6">M7263 (KD11-D) CPU</td><td>1</td></tr>
<tr><td colspan="6">M7847 16K MOS MEMORY</td><td>2</td></tr>
<tr><td colspan="6">M7847 16K MOS MEMORY</td><td>3</td></tr>
<tr><td>N.C.</td><td>N.C.</td><td colspan="4">3764</td><td>4</td></tr>
<tr><td colspan="2">M9312</td><td>N.C.</td><td>N.C.</td><td>N.C.</td><td>N.C.</td><td>5</td></tr>
<tr><td colspan="2">M7850</td><td colspan="4">DSD 8830</td><td>6</td></tr>
<tr><td>N.C.</td><td>N.C.</td><td colspan="4">M7859</td><td>7</td></tr>
<tr><td>N.C.</td><td>N.C.</td><td colspan="4">M7860 (DR11-C)</td><td>8</td></tr>
<tr><td colspan="2" rowspan="3">M920
BUS JUMPER</td><td>N.C.</td><td>G727A</td><td>N.C.</td><td>N.C.</td><td>9</td></tr>
<tr><td colspan="4">BLANK SPACE</td><td>10</td></tr>
<tr><td colspan="4">M7219</td><td>11*</td></tr>
<tr><td colspan="2">M9680A</td><td>M208</td><td>M208</td><td>M7821</td><td>M796</td><td>12</td></tr>
<tr><td>G772B</td><td>M205</td><td>M611</td><td>M611</td><td>M112</td><td>M113</td><td>13</td></tr>
<tr><td colspan="2">M9302</td><td>M957</td><td>M957</td><td>M116</td><td>M239</td><td>14</td></tr>
</table>

*Modules in slots 11-14 constitute the DR11-B

Figure 3.1 PDP-11/04 Module Configuration

3. Terminal Interface

A 3764 serial interface board is used instead of a DL11-W to connect one of four terminals to the Unibus via a four position Inmac switch.

4. Bootstrap/Terminator

An M9312 is used instead of the DEC standard M9301 Bootstrap/Terminator.

5. Parity Controller

The M7850 parity controller generates and checks parity on stored data and also contains a 16-bit control and status register (CSR).

6. Storage Medium

A DSD 8830 interface board provides the link to the hard and floppy disks. This board emulates both the DEC RX02 and RL02 devices. It also contains the system's bootstrap at location 771000.

7. Programmer's Console

The programmer's console is designated as KY11-LB and is connected to the Unibus via an interface module, M7859. The console contains the power switch, a switch register, a six-digit seven-segment display, and a keypad for controlling the computer and examining data or addresses. The key pad is used for booting the system in the present setup.

8. <u>General Device Interface (DR11-C)</u>

The DR11-C is contained in a single module, M7860, for linking the Quantimet System 23C Control Interface module to the Unibus. (See Section B of this chapter.)

9. <u>Bus Grant Jumper G727</u>

This is placed in the open small peripheral controller (SPC) section in slot nine to provide continuity.

10. <u>Direct Memory Access Interface DR11-B</u>

The DR11-B consists of a set of modules confined to the four slot DD11-CK backplane which is connected to the nine slot DD11-PK backplane via a M920 Bus Jumper. This interface links the FIFI module in the Quantimet System 23C to the Unibus. (See Section C of this chapter.)

11. <u>Bus Terminator</u>

The Unibus is terminated with the M9302 module.

B. GENERAL DEVICE INTERFACE (DR11-C)

The DR11-C provides the control interface between the computer and the image analyzer for transferring module switching instructions under program control. It is connected to the Unibus at the computer end and to the Control Interface module in the Quantimet via a multiway control bus cable which is terminated at the Control Interface module on the NPS system. The DR11-C communicates with the Unibus to accomplish three functions: address selection, interrupts, and 16-bit program-controlled data transmission. The DR11-C uses three 16-bit registers to provide the interface. These are the input buffer register (DRINBUF), the output buffer register (DROUTBUF), and the control and status register (DRCSR). These registers are installed in the NPS system at the standard addresses as indicated below:

Register	Address (octal)	System 23 Acronym
DRCSR	767770	DRCST
DROUTBUF	767772	DRCOUT
DRINBUF	767774	DRCIN
VECTOR	300	DRCVEC

The input buffer is a read-only register from the Unibus and is nonlatching, requiring data to be held on the line until the transfer is complete. This register receives data from the CIF for transferring to the Unibus.

The output buffer is a read/write register and is used to transfer data from the Unibus to the CIF.

The control and status register contains the logic for interrupts, and command and status functions. Only six bits of the register are used to accomplish these functions, two for each function, as illustrated below in Figure 3.2.

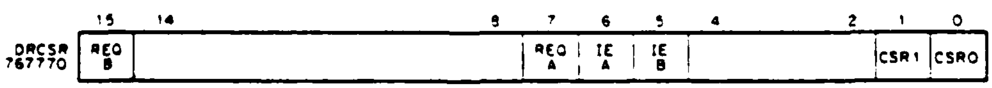


Figure 3.2 DR11-C Control and Status Register
[Ref. 8, Figure 2-1]

The REQ-A and REQ-B bits are set under control of the CIF module and are used to request interrupts. Bits IE-A and IE-B are set under program control to enable the interrupts requested by REQ-A and REQ-B respectively. In the NPS System 23, only B interrupts are used for data transfers. The CSR0 and CSR1 bits are set under program control to perform user-defined commands. The System 23 uses only CSR0 and uses it to perform a bus reset operation.

C. DIRECT MEMORY ACCESS (DMA) INTERFACE DR11-B

The DR11-B module provides access to the computer's memory for the Quantimet FIFI module via the Unibus. The two modules are connected by two multiway cables. The DR11-B communicates with the Unibus to perform four functions: address selection, interrupt control, Unibus master control logic, and device interface. It uses three 16-bit and one 15-bit registers to accomplish the DMA interface. These are the word count register (DRWC), bus address register (DRBA), data buffer register (DRDB), and command and status register (DRST). They are assigned the standard addresses as listed below:

Register	Address (octal)	System 23 Acronym
DRWC	772410	DRWC
DRBA	772412	DRMA
DRDB	772416	DRDB BA
DRST	772414	DRST DRCOM
VECTOR	124	

These registers may be operated in either slave or master mode. In the slave mode, data transfers are performed under program control; and in master mode the DR11-B gains control of the Unibus and allows the user device to either transfer data directly to memory, or to perform an interrupt function.

The word count register is a read/write register and contains the number of words to transfers in two's complement format.

The bus address register is a 15-bit read/write register. These fifteen bits denote the address of the word to which the data will be transferred. The sixteenth bit, Bit 0, denotes the odd or even byte in the word and is usually even by default. However, it is available for control by the user device to provide for odd byte addresses. FIFI uses this bit to provide for contiguous storage of image data, which is represented in bytes, when an odd number of bytes are transferred for each column.

The data buffer contains the data to be transferred to FIFI or to the computer. It operates in two modes: as an output buffer it functions as a latching, write-only register providing output to FIFI; and as an input buffer it is nonlatching, read-only, and the data provided by FIFI is held on the lines until the data is transferred.

The command and status register contains the interrupt logic, and command and status functions. The contents of this register are illustrated in Figure 3.3.

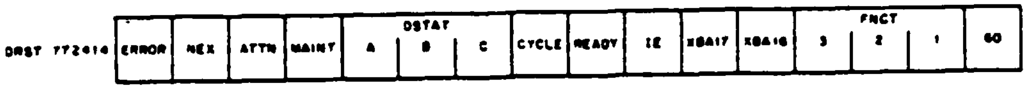


Figure 3.3 DR11-B Status and Command Register
[Ref. 9, Figure 2-1]

The significant portions of this register are the device status bits, (9,10,11), and command function bits, (1,2,3). The device status bits' contents are provided by FIFI to designate the type of data transfer that will be made. The command function bits are program controlled and provide data transfer sequence instructions for the FIFI module. Descriptions of the other bits' functions are contained in Reference 9.

D. COMPUTER SOFTWARE

This section contains information pertaining to the use of DEC Software that is necessary or useful for operating the NPS system in the computer-controlled mode.

1. Operating System

The operating system used is the standard RT-11 Version 4.0 Single-Job monitor. Two other monitors, (Foreground-Background and Extended Memory), are available; but the Single-Job monitor provides all the necessary capabilities and its quick handling of interrupts is well-suited for interfacing with the Quantimet. Furthermore, the

Extended Memory monitor is not compatible with the present PDP-11/04 hardware, nor is it compatible with the QLINK software.

The Single-Job operating system is identified as RT11SJ.SYS. When the system is bootstrapped, the operating system reads the startup command file, STARTS.COM, to define the computer system's logical configuration. The operating system communicates, by default, with one of two Logical devices. These are the system device and the data device. These are identified by the Logical device names SY and DK, respectively. Presently, the STARTS.COM file assigns both of the Logical devices to the Winchester disk which is designated by the Physical device name DL0. The floppy disk's Physical device name is DY0 and, unless a change is made to the Logical device assignments mentioned above, the Logical device identifier, (DY0:), must be included in the command string. Currently, the floppy diskette is used only to copy files onto or off of the Winchester disk. The large capacity of the Winchester obviates the need for separate system and data devices and presently all necessary Logical devices are assigned to it. The status of the current device assignment may be viewed on the terminal by using the SHOW command.

Another required file, which is used by the operating system, is the SWAP.SYS file. This is used by the operating system to swap program sections in and out of main memory.

2. Device Handlers

These programs provide the interface for the peripheral devices:

TT.SYS - required for the LA36 Decwriter
DY.SYS - required for the Floppy Diskette
DL.SYS - required for the Winchester Disk

3. Utility Programs

The following programs are useful for file transfer and editing:

KED.SAV
PIP.SAV
DUP.SAV
DIR.SAV
PATCH.SAV

KED.SAV is the system's editor as assigned by the STARTS.COM file. PIP.SAV and DUP.SAV are used by the operating system to perform file transfer operations. DIR.SAV provides a directory of the system's files. PATCH.SAV is useful for making changes to an executable program file without changing the source file and then recompiling and relinking. This program is necessary for making changes to some of the System 23 software as some are available only as executable files, i.e., with file type .SAV. Instructions for using these and other programs can be found in Reference 20.

4. Language Processors

Processors for FORTRAN, Macro, and BASIC are available on the system device. The online debugging tool, ODT.OBJ , is available for linking to object files to assist in debugging the programs.

a. FORTRAN

RT-11 FORTRAN Version 2.5 is the present system's FORTRAN compiler and it was built to produce threaded code by default to be compatible with the PDP-11/04 hardware. The standard FORTRAN library, FORLIB.OBJ, was built into the system library, SYSLIB.OBJ. The files required for using FORTRAN are listed as follows:

```
KED.SAV
FORTRA.SAV
LINK.SAV
SYSLIB.OBJ
```

KED.SAV is used to write the source code and FORTRA.SAV is used to compile the program. The LINK.SAV program is the standard RT-11 program for linking object files into executable files. LINK.SAV uses the system library, SYSLIB.OBJ, to resolve references made to system library routines. Instructions for developing FORTRAN programs for the NPS System 23C are included in Appendix C.

b. Macro

The Macro-11 assembler is required when changes to the standard QLINK libraries are desired. The files necessary for its use are listed below:

```
MACRO.SAV
SYSMAC.SML
```

MACRO.SAV is the assembler and SYSMAC.SML is the system's Macro library that contains callable systems routines that may be useful in Macro assembly language programs. It is functionally equivalent to SYSLIB.OBJ.

c. BASIC

The BASIC language processor is provided with the Quantimet, but with no supporting documentation, and its operation has not been verified.

E. SUMMARY

This completes the description of the PDP-11 computer, the device interface modules, and the software as they pertain to control of the Quantimet. Now that both machines have been discussed, the next chapter will address the process used to implement the interface between them.

IV. IMPLEMENTING THE COMPUTER INTERFACE

This chapter contains a summary of the steps taken to establish computer-control for the NPS System 23C. In order to understand the computer interface, it was first necessary to become proficient with both the computer and the Quantimet as separate units. Becoming familiar with the PDP-11 computer and the RT-11 software was relatively straight-forward as sufficient documentation is available for these. Unfortunately, this was not the case for the Quantimet. Documentation is available, however it is incomplete, often irrelevant and requires considerable effort to assimilate. The most serious deficiency is that many of the documents describing the computer interface are missing.

A. INITIAL STATUS AND SYMPTOMS

During previous research, [Ref. 2], the Quantimet modules used for the manual mode operations were tested and repaired by a manufacturer's representative. However, the proper functioning of the interface modules was not verified, and at the beginning of the present project their status was unknown. Initial attempts to run the System 23 Standard Routine gave inconsistent and confusing results. A significant part of the confusion resulted from initial unfamiliarity with the Quantimet and lack of clear instructions for using the system in the computer-controlled mode.

The problems associated with using the Quantimet can be categorized according to the operating mode in which they occurred. Once this distinction was made, the cause of the problems that occurred in the manual mode could be identified and resolved. However, the problems experienced in the computer-controlled mode were pertinacious.

The following problems were identified with the Quantimet during this project:

* Intermittent Variable Scale Function. The variable scale display occasionally disappeared.

* Intermittent Light Pen Operation. Light Pen measurements were not consistent.

* Inaccurate Feature Measurements. Occasionally, the feature measurement result was unusually large and obviously incorrect.

* No Computed Display in Computer Mode. When Q.SAV was run, no program response was indicated on the Quantimet display.

* Display Trashed in Computer Mode. When Q.SAV was run, the computed display would fill the screen with vertical strips similar to the horizontal ones obtained with the Frame Smasher.

* Flashing Busy Lights in Computer Mode. Most of the time when Q.SAV was run, the program would not correctly proceed; the External Busy lamp on the CIF and the Busy lamp on FIFI would simultaneously flash.

The last of these listed problems was the single persistent obstacle in establishing the computer interface.

B. CORRECTIVE ACTIONS

In this section the solutions to the previously listed problems are summarized.

The cause for intermittent Variable Scale operation was determined to be a poor twisted pair connection.

The Light Pen's problems may have been another bad connection or operator error. Procedures for using the Light Pen in the NPS system have been written and are included as Appendix B.

The incorrect feature measurements eventually deteriorated to the point that the Function Computer module was removed and sent to the manufacturer for repair.

To resolve the problems experienced with the computer-controlled mode the first step was to insure that the wiring agreed as close as possible to the software installation notes for the System 23C, [Ref. 13]. This resolved the alphanumeric display problem by including the FIFI display connector in the computed display daisy chain.

The cause for the trash on the computed display was determined to be the collector display's input to the daisy chain. This problem was later observed in the manual mode as well. The problem has not been repaired, and the Collector display must be turned off to use the system.

The remaining problem, the cyclic flashing of the busy lights on the CIF and FIFI modules, was inconsistent and frustrating. On some occasions the Q.SAV routine would come on-line and progress satisfactorily for awhile and then hang-up. Most of the time the response to running the Q.SAV program was a synchronized flashing of the CIF's Ext-Busy and the FIFI's Busy lights. In Reference 17 this symptom is said to indicate that the computer is waiting for the Quantimet and is probably caused by lack of the "auto" signal from the CIF. The wiring for the "auto" signal was verified, but to no avail.

Because of the system's poor response with the Q.SAV program, the stand-alone FORTRAN demonstration programs and test programs were tried. For the FORTRAN programs, this required learning the necessary compiling and linking procedures for the System 23 software. These have been included in Appendix C. The response obtained from these programs was identical to that obtained with the Q.SAV program. But, at least the source code was available for the demonstration programs as well as the QLINK assembly source files. This permitted using the RT-11 debugger, ODT, to isolate the routine associated with the busy lamp cycling.

The results from using ODT with the DENIMG.FOR program indicated that the fault occurred within the QLINK source routine DRBINI, which is responsible for initializing the interface between the DR11-B and FIFI. At this point a test program was written to further isolate the cause of the problem. This program contained only calls to interface initialization and termination routines. By using this approach, the portion of the program that was associated with the flashing busy lamps was found to be an indefinite loop.

Without any documentation to describe the source routines, it can only be surmised that an interrupt must occur to exit the loop. Again this pointed to the interface between FIFI and the DR11-B.

The FIFI module was removed from the console and visually inspected for obvious discrepancies; none were found. The connectors and printed circuit boards edges were cleaned, and then it was reinstalled. Again, the same response resulted. Once again, the FIFI module was removed and the available schematics were located to make a more detailed inspection. The findings and solution to the problem are described below.

On the master control board is a 7-pin dip switch that controls the operation of the FIFI module. This switch is mentioned in the FTEST program, but no indication is made in the test procedure for the switch settings for normal operation. It was noted that the switch settings were not the same as specified in the last step of the FTEST procedure, nor did they match any of the switch settings indicated earlier in the test procedure. A telephone call to the manufacturer verified the switch settings were incorrect. The proper switch positions for the dip switch are pins 1,2,3,6: ON and 4,5,7: OFF. After correcting these, the Standard Routine and interface test programs functioned better: The system would still hang-up, but not as regularly.

The TCIF program was used to finally resolve the problem. This program has the capability of manually issuing the "auto" signal to FIFI, and it was by repeatedly using this that the FIFI and CIF were forced into an acceptable state. Apparently, when the program was terminated by hanging-up instead of by using the interface termination routines, the next attempt to use the computer interface would find the system in an undefined state that could not be resolved with the initialization routines. However, by using the manual "issue auto" command in the TCIF program this state could be corrected. This technique was used successfully and now the system works consistently in the computer-controlled mode. Other problems were later identified with individual modules in the System 23, but by reconfiguring the modules' wiring these were bypassed and results were obtained using the computer-controlled mode of the NPS System 23.

C. SUMMARY

Having described the solution to the problems that prevented computer-control of the Quantimet, instructions for operating the NPS System 23 in the computer mode will now be given.

V. COMPUTER-CONTROLLED OPERATION OF THE SYSTEM 23C

This chapter describes the procedures for using the NPS System 23 in the computer-controlled mode. The emphasis is on using the Standard Routine, but the equipment setup applies to user developed FORTRAN or BASIC programs, and the System 23 test programs.

A. EQUIPMENT SETUP

As in the manual mode of operation, before any measurements can be performed, an acceptable video signal must be supplied to the detector module. This is accomplished by initially focusing the image and then setting the parameters on the System Control module. These include the Plumbicon Scanner's light integration, the sensitivity and white levels, and the shading correction. The details for setting these are contained in Chapter 4 of Reference 5.

The following is a list of the module switch settings necessary to accomplish computer-controlled operation of the NPS System 23C. It differs from those found in Reference 13 as they apply to a standard System 23C configuration. The necessary wiring connections are included in Appendix F.

Of the following module settings, the only one that is vital to the computer-controlled mode is the System Control module's CONTINUOUS-AUTO/SINGLE SCAN switch. This switch determines how the measurement scan is initiated. It must be in the AUTO/SINGLE SCAN position in order for the Control Interface module to coordinate the measurement scan with the computer program. Generally, all other modules' switches are placed in the AUTO position. Switch positions that are applicable to the computer mode operations are marked with an *.

MODULE Switches	POSITION
SYSTEM CONTROL	
PLI	x1
Accumulator-Acc	Down
Average	Down
Intercept-Area	*Area
Continuous-Single Scan/Auto	*Single Scan/Auto
DISPLAY	
All display switches	Up or Center
1D AUTO DETECTOR	
Detected Function	*Either Slice Position
Detected Selector	*Auto
Emphasis	Off
Attenuation	Off
Display	Up
Auto Delineator	Up
MS3 STANDARD ANALYSER	
Input	*Auto
Sizer	*Up
> <=	>
Key 1	*Up
Key 2	*Center
Key 3	Center
End-Full	Full
Function Selector	*Auto
Display	Center
FUNCTION COMPUTER	
Input	Normal
Function Selector	*Auto

CLASSIFIER-COLLECTOR	
Sizer	Off
Transfer Switch	*Auto
Classifier Display	Up
Function Selector	*Auto
Collector Display	*Down(Until Repaired)
CIF	
CIF Display	(A) Detector
Interface	
Control-Off	*Control
Run-Stop	*Run
FIFI	
Function Selector	*Auto
Computer	*Continuous
Display	*Up

B. USING THE STANDARD ROUTINE

This section contains information for using the standard routine, Q.SAV, on the NPS system. Only a portion of the program's capabilities were used during this effort and only the procedures for using these are described below. The program is described in detail in References 11 and 12.

1. Necessary Files

The following System 23 files are required in order to use the standard routine:

CONFIG.SAV
Q2DAT.CAL
Q.SAV

Generally, they should be on the system device, SY. If any output is to be stored, then the Logical device, QD, must be assigned to a Physical device. Presently, this is performed by the RT-11 system STARTS.COM file. The CONFIG.SAV program usually needs to be run only once for a particular system.

As described in Section II.E, this program defines the configuration of the system to be used by the Q.SAV program.

2. Starting the Standard Routine

In order to run the standard routine, the Quantimet modules should first be set as indicated in Section A. Then the monitor command R Q should be issued. From this point on, the terminal is under control of the 'Q' program and key strokes are interpreted as the image analysis instructions shown in Figure 5-1. For example, pressing <s> is interpreted as <DISPLAY> and pressing upper case <S> is interpreted as <LABEL>. The keyboard is interpreted as a standard System 23's, so some of the keys represent inapplicable instructions and cause to program to abnormally terminate. These keys are listed below in Table V.1.

TABLE V.1 UNDEFINED KEYS ON THE NPS SYSTEM 23

UPPER CASE	lower case
	X SIZE
	Y SIZE
DILATE	
FRM H	
FRM W	FOCUS
FRM C	FRM JOY
EDIT	
DENS D	
DENS L	

Use of these keys will cause the control bus to lock up and require the system to be rebooted. All normal program responses will be only on the Quantimet display and not on the terminal. One exception is when text strings are entered during the program's execution. These are printed at the terminal as well as on the display screen.

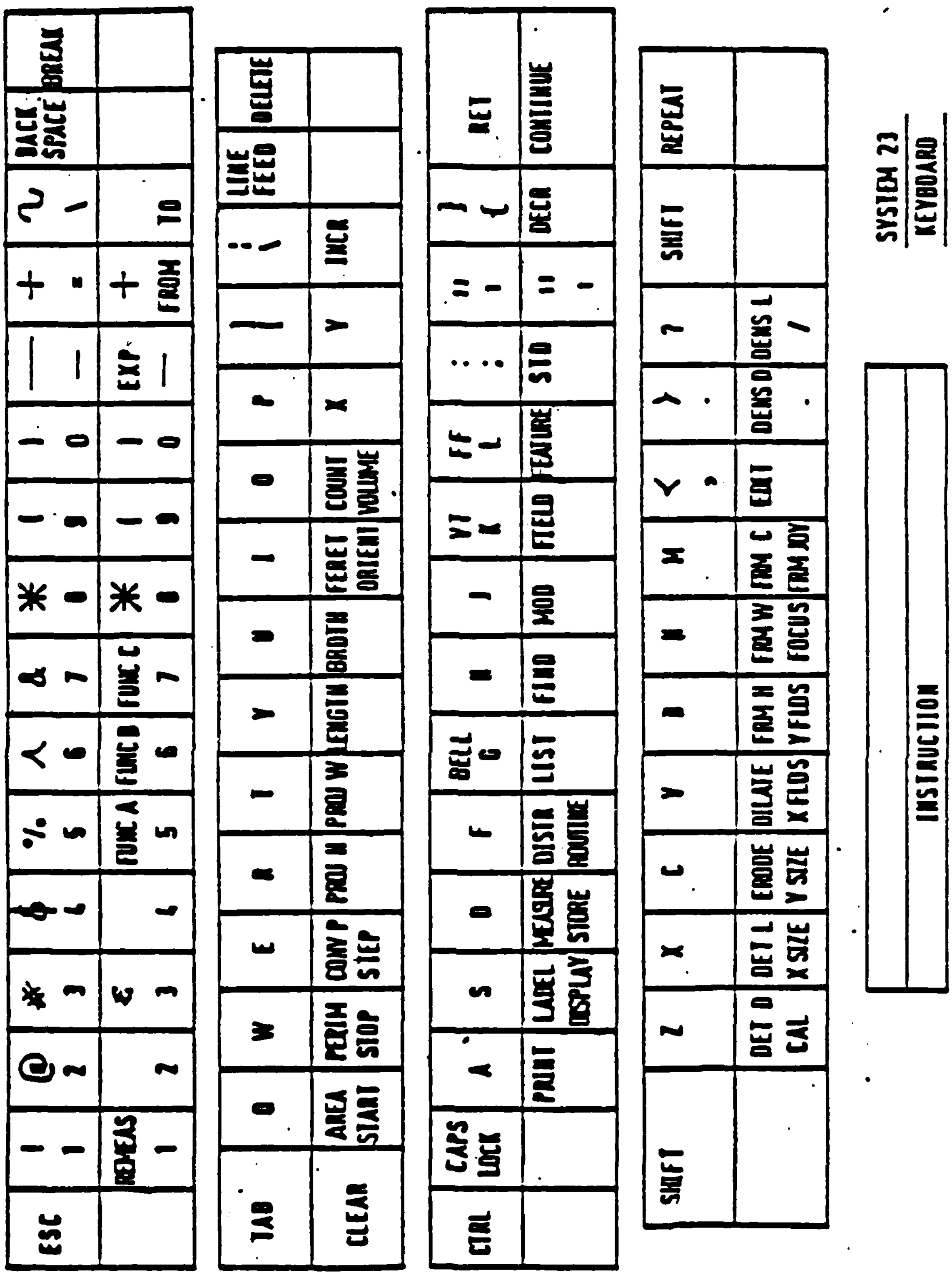


Figure 5.1 System 23 Keyboard [Ref. 11]

If the date has not already been set, the routine will provide a prompt to do so. After the date is set, the program responds with DISPLAY ROUTINE and waits for operator input. At this point, there are two valid replies. One is pressing the <STD> key and the other is entering an integer followed by <CONTINUE>. The integer entry applies only if routines have previously been created from the Standard Routine, (see Section 5). The selected routine is displayed and the next action taken by the operator depends on the desired operating mode. The operating modes are described in Section 4.

3. Standard Routine Instruction Format

A routine is composed of individual Instructions beginning with Instruction 0 and ranging up through 99. The format for each of the first three Instructions is unique. The formats for Instructions 3 thru 99 are all the same. Refer to Figure 5.2 for the following discussion. (Also see Figures A.2 and A.5.)

Instruction 0 contains text comments that may be entered by the operator as desired. Usually, these would include useful identification or directions for the routine.

Instruction 1 contains information pertaining to the system's configuration and calibration. This information is obtained from the Q2DAT.CAL file that was produced by the CONFIG.SAV program. The only entry that is germane to the NPS system is the number of fields. The

TITLE AND OPERATOR NOTES		INST Ø	ROUTINE
CALIBRATION STAGE SETTINGS SPECIMEN SPECIFIC SETTINGS		INST 1	
SPECIMEN SPECIFIC SETTINGS FIELD 1 TASKS		INST 2	
DETECTOR	HARDWARE STATUS	INST 3	
DENSITOMETER			
AMENDER			
FRAME			
EDITOR			
FIELD LIMITS 0 - 9	SOFTWARE STATUS		
FEATURE LIMITS 0 - 9			
FIND			
FIND EDIT			
MEASURE	TASKS		
PRINT			
LIST			
LABEL			
		INST 4	

Figure 5.2 Standard Routine Instruction Format [Ref. 11]

product of X and Y field numbers determines the number of image fields to be analyzed. All other peripheral settings shown in Instruction 1 are not available in the NPS system and any explicit reference to them must be avoided, e.g., pressing the FOCUS key will lock-up the control bus and require rebooting the system. Additional text may be inserted after the Calibration entry, (see Figure A.5).

Instruction 2 contains information and commands that pertain to the initial settings for the Quantimet modules. In general, these supplement the settings contained in Instruction 1, but in the NPS system its use is limited to selection of the Specimen Standard detection threshold. This will cause all fields to be analyzed at the threshold that is automatically determined by the 1D Auto Detector for the first field.

Instructions 3 and onward are performed in a loop for each field until all the fields which are specified in Instruction 1 have been analyzed.

The format of Instruction 3, et al, contains three categories. These are hardware status, software status, and measurement tasks.

The hardware status specifies the Quantimet's modules' settings applicable to the current Instruction. In the NPS system this is limited to detection threshold and chord sizing.

The Software Status specifies logic to determine if certain fields or features are acceptable for performing measurement tasks. Only the fields and features meeting these criteria will be used for measurement during execution of the current instruction. The field and feature limits are defined by expressions containing measurement parameters. For example, a field limit of AREA from 0 to 50 will restrict all measurements to those features that have an area less than 50. Combination of the parameters may be used in the expression to perform pattern recognition criteria. (See Section II.B.4.)

The measurement tasks are as defined and entered by the operator.

4. Modes Of Operation

The Standard Routine may be operated in one of three modes: Programming, Immediate, or Run. The mode of operation allowable depends on the program's state. Three states may be considered as DISPLAY ROUTINE, DISPLAY INSTRUCTION, and RUNNING. The flow chart included as Figure 5.3 depicts the different states and modes for the program. A typical scenario for using the routine follows. When the program is begun and the date is established, the program automatically enters the DISPLAY ROUTINE state. The next step is to write a routine that will perform the desired measurement task. This is done by entering the DISPLAY INSTRUCTION state by pressing <DISPLAY> <INSTRUCTION> and

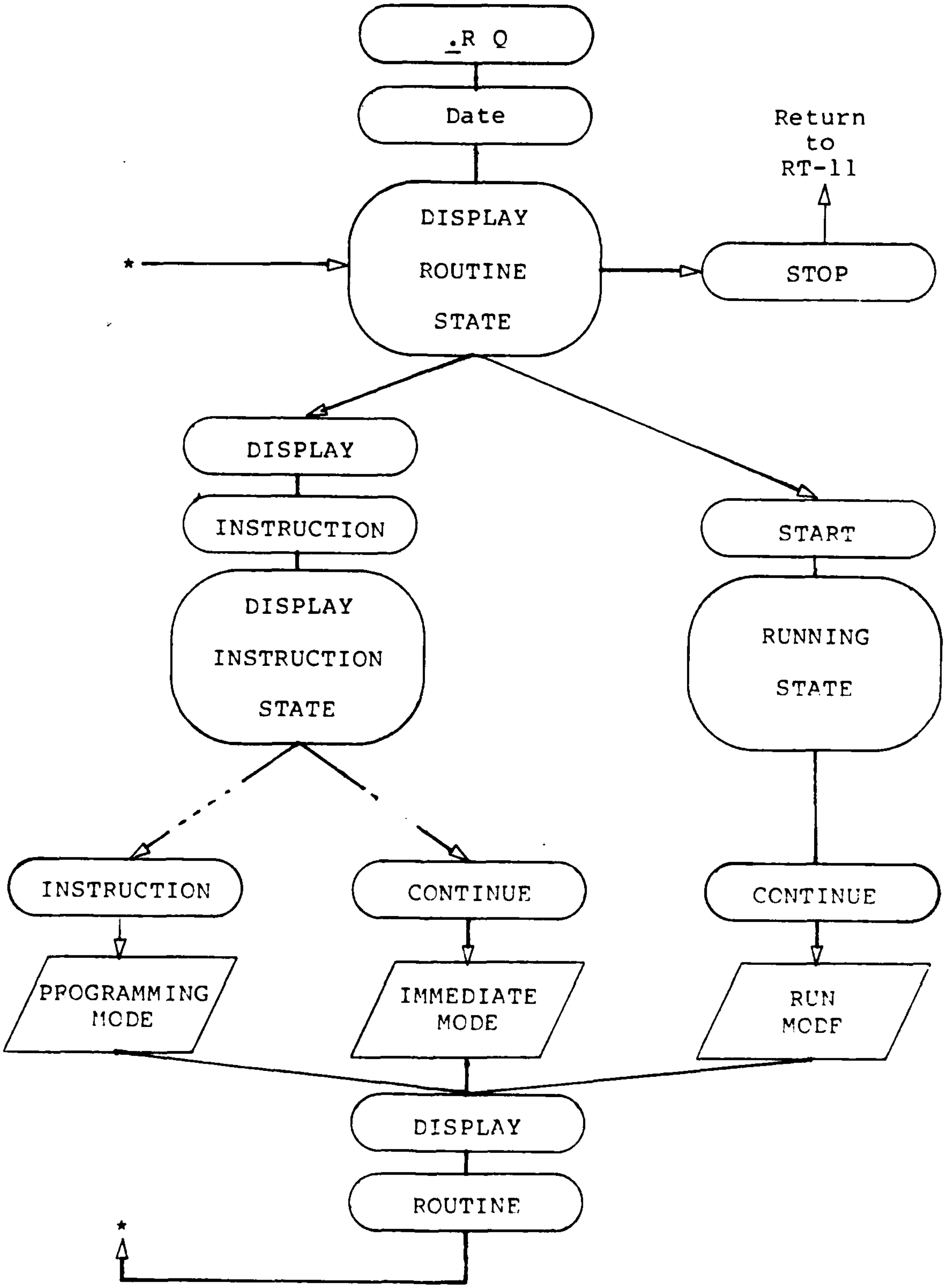


Figure 5.3 Standard Routine Modes and States

progressing through the Instructions beginning with Instruction 0. Measurement commands are entered and then followed by pressing <CONTINUE> to immediately observe the results, hence it is called the Immediate Mode. Once the correct measurement sequence is determined, the measurement sequence is entered and then followed by pressing <INSTRUCTION>. This stores the measurement sequence in the current Instruction, hence it is called the Programming Mode. When all desired measurement sequences have been determined and programmed into a routine, pressing <DISPLAY> <ROUTINE> will change the state to DISPLAY ROUTINE and the routine may then be run by pressing <START>. This changes the state to RUNNING and the necessary actions are performed as prompted by the routine e.g., moving or focusing the image. These actions are repeated until all fields have been analyzed and the routine is completed. Pressing <DISPLAY> <ROUTINE> will change the state back to DISPLAY ROUTINE.

5. Creating and Storing Routines

The Q.SAV programs has provisions for developing unique routines based on the STD routine, (or any other previously stored routine), and then storing these on disk. The file is identified as Q2PIII.QTM, where III is an operator defined integer. The sequence of steps to store the routine is as follows. Before the Q.SAV program is run a Logical device assignment QD must be made. Presently, the

RT-11 STARTS.COM file makes this assignment to the Winchester disk. The routine is created in the Programming Mode as discussed in Section 4, and upon return to the DISPLAY ROUTINE state, the Instruction sequence <STORE> <ROUTINE> <III> <CONTINUE> will store the routine Q2PIII.QTM on the QD device.

C. SUMMARY

This concludes the discussion of operating the NPS System 23 in the computer mode. In this chapter instructions for using the Standard Routine have been given, which included the equipment setup and a description of the structure and the use of the Routine. The next chapter presents the results produced by the Standard Routine when it was used to obtain particle information.

VI. PRELIMINARY RESULTS

This chapter contains the results of using the Quantimet 720 in the computer-controlled mode to obtain particle size distributions from a calibration standard reticle. The procedures used are contained in Appendix A. The reticle consists of about 10,000 circular discs of twenty-three sizes ranging from a diameter of 5 to 93 microns. These particles are photo-etched at random positions within an 8 millimeter circular area. Next to this is a quality control array of the twenty-three sizes of particles which is used for calibration (see Fig. 6.1).

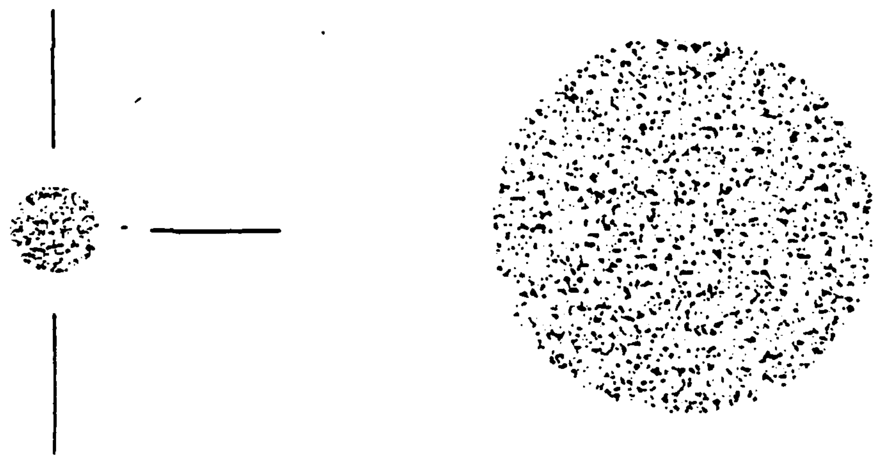


Figure 6.1 Calibration Standard Reticle
[Ref. 21, Figure 1]

The particle size distribution provided by the manufacturer for the reticle was used for comparing the results obtained from the Quantimet. This distribution is a measured quantity and represents an 'effective' size distribution. This distribution including their specified errors is plotted in Figure 6.2. [Ref. 22] The actual distribution of particle sizes photo-etched on the reticle was not provided by the manufacturer. This distribution does not account for any particle overlap which obviously exists as seen in Figures 6.4 and 6.5. [Refs. 21 and 22.]

A. CALIBRATION STANDARD RETICLE

Figure 6.3 is a histogram of particle count density that was constructed from data obtained by using the System 23 Standard Routine. A routine was written to plot End Count as a function of maximum chord size for a sampled area of the reticle. Comparing this figure with Figure 6.2 it can be seen that the distribution is skewed toward the larger size particles. This results from the effects of particle overlap. Using End Count reduces this effect as illustrated in Figures 6.4 and 6.5, but the effects of particle cluster orientation with respect to the horizontal scan and the amount of particle overlap remain, especially when smaller particles are completely inside larger ones. Figure 6.6 is a cumulative plot of the data contained in Figures 6.2 and 6.3 to present another perspective of the results. The effects of particle overlap cause the curve for the experimentally obtained data to be higher then that for the manufacturer's data.

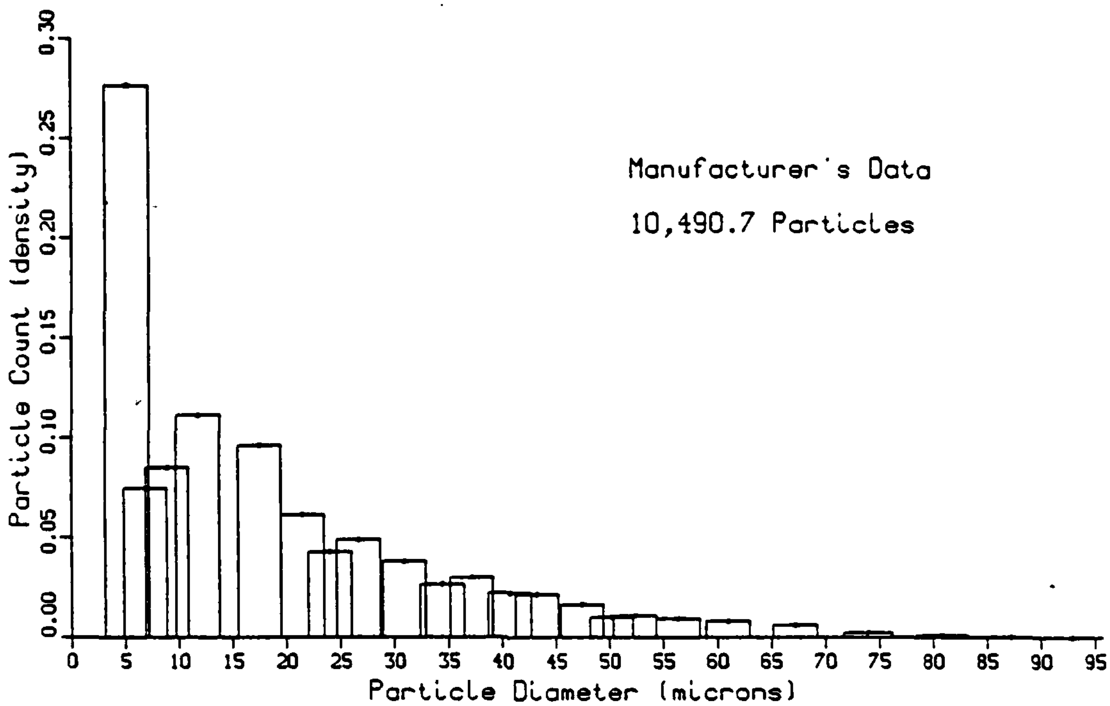


Figure 6.2 Manufacturer's Size Distribution

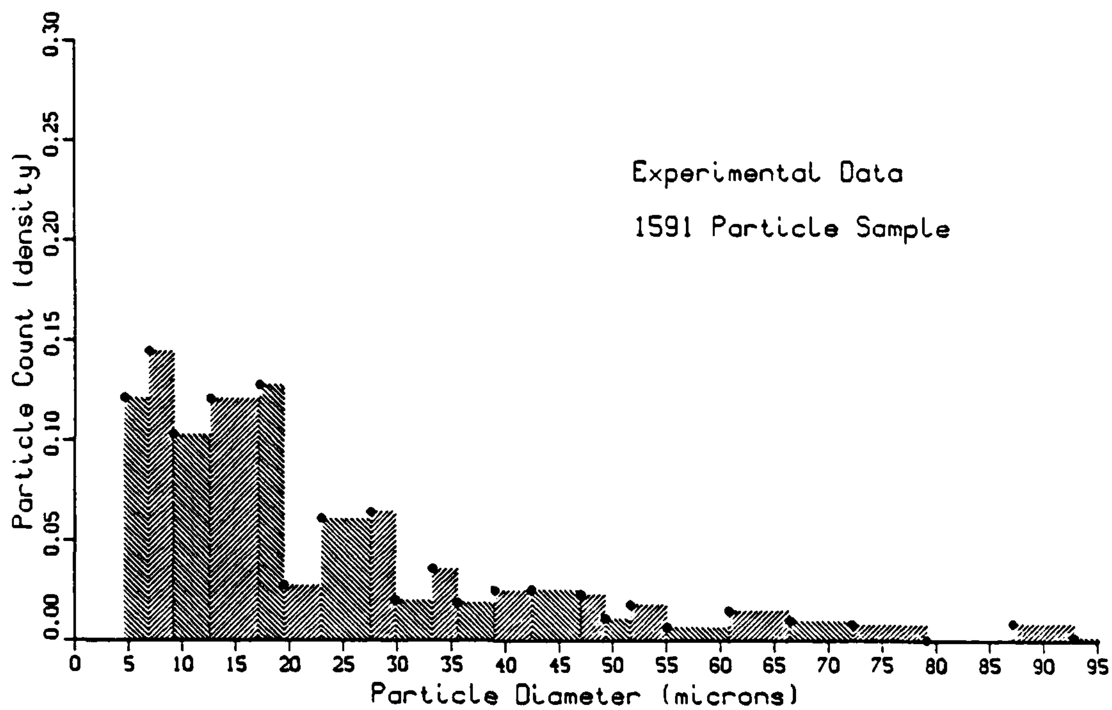


Figure 6.3 Experimental Size Distribution

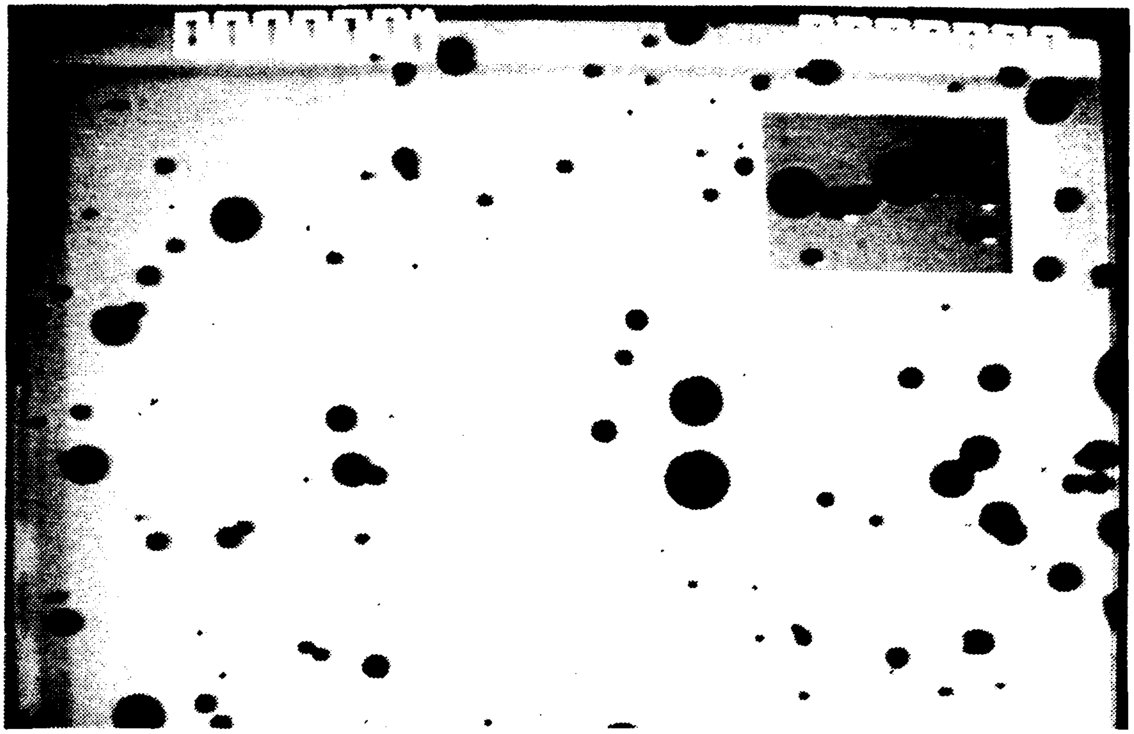


Figure 6.4 Full Feature Count Measurement

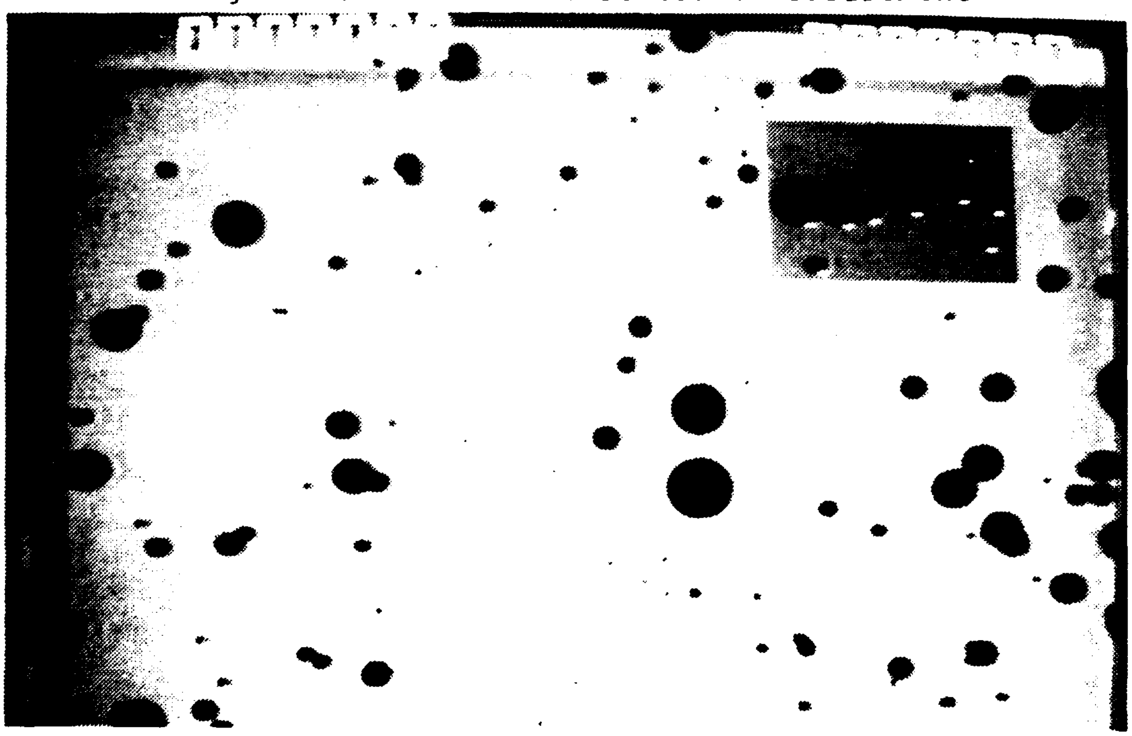


Figure 6.5 End Count Measurement

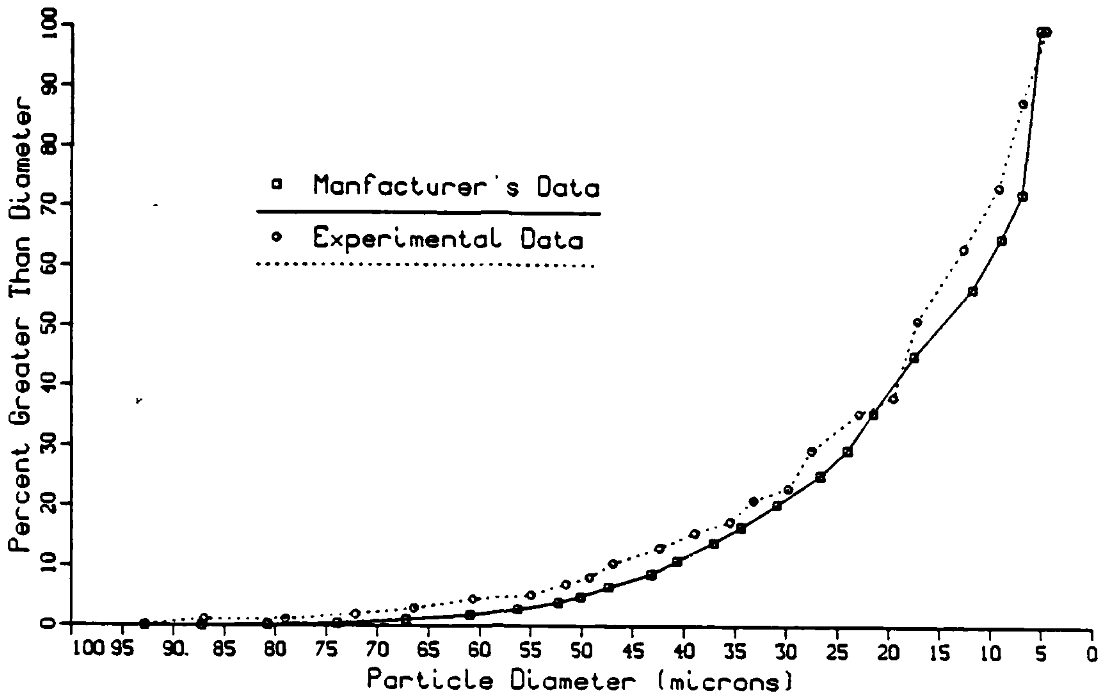


Figure 6.6 Comparison of Cumulative Size Distributions

B. HOLOGRAM OF CALIBRATION STANDARD RETICLE

Obtaining results from the hologram is considerably more difficult than from the reticle illuminated by white light. Many factors are responsible for this. First, the overall brightness and consequently the contrast of the holographic image is limited by the laser's output intensity. This low light level requires increasing the scanner's light integration from one scan to five or twenty-five scans. This drastically slows down every facet of the measurement process. The next obstacles in analyzing the hologram are the loss of sharpness and resolution in the image caused by speckle. The speckle effectively obliterates all particles less than 30 microns in diameter. Other factors complicating the process are uneven illumination and focus across the image. These require manually readjusting the detection level and focus for each field. This is especially difficult at the slower scan rates. The consequence of these factors is that no meaningful particle size distribution can be obtained from the holograms with the present equipment setup.

Figures 6.7, 6.8, and 6.9 illustrate the problem of distinguishing the particles from the background. Ideally, the contrast levels in the video image should be such that the gray level of the object is significantly different from that of the background. This is achieved when the reticle is illuminated by white light as seen in Figure 6.7 where the particles are at a gray level near seven and the background is near a much higher gray level of fifty-three. The results obtained for the holograms, as illustrated in Figures 6.8 and 6.9 are much different. First, the low light level of the image causes a decrease in the background gray level and much wider distribution of it. The poor contrast between the particles and the background precludes distinguishing the particle from the background. This depicts the essence of the detection problem: without being able to properly detect the particles no meaningful particle measurements can be made using the System 23.

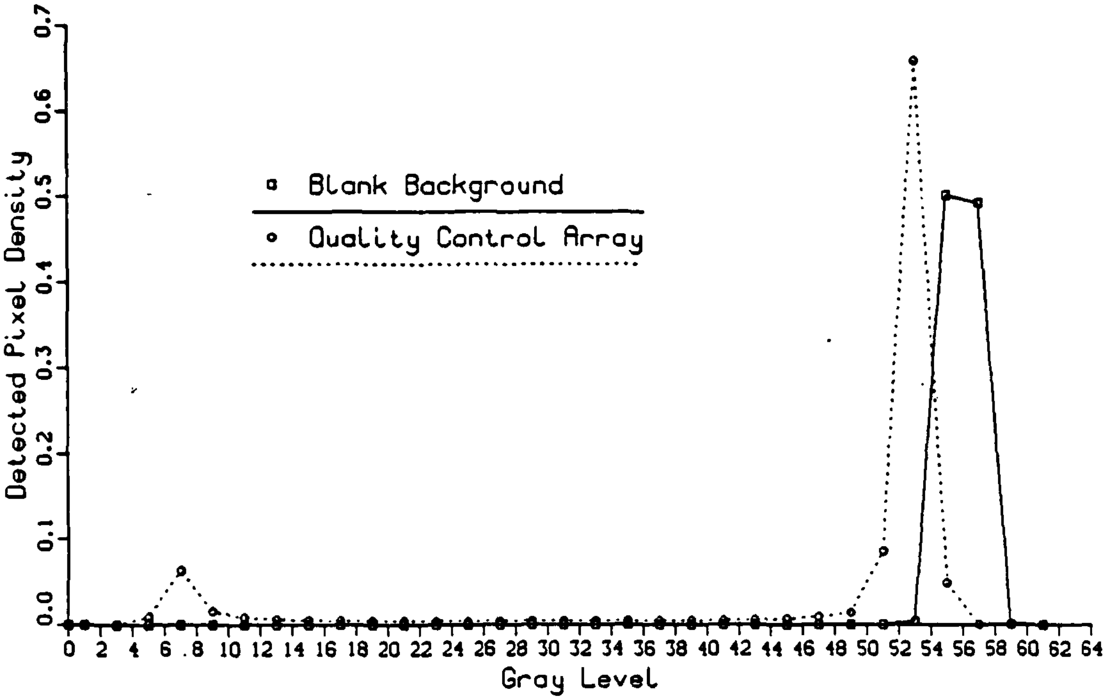


Figure 6.7 Gray Level Distribution of Reticle

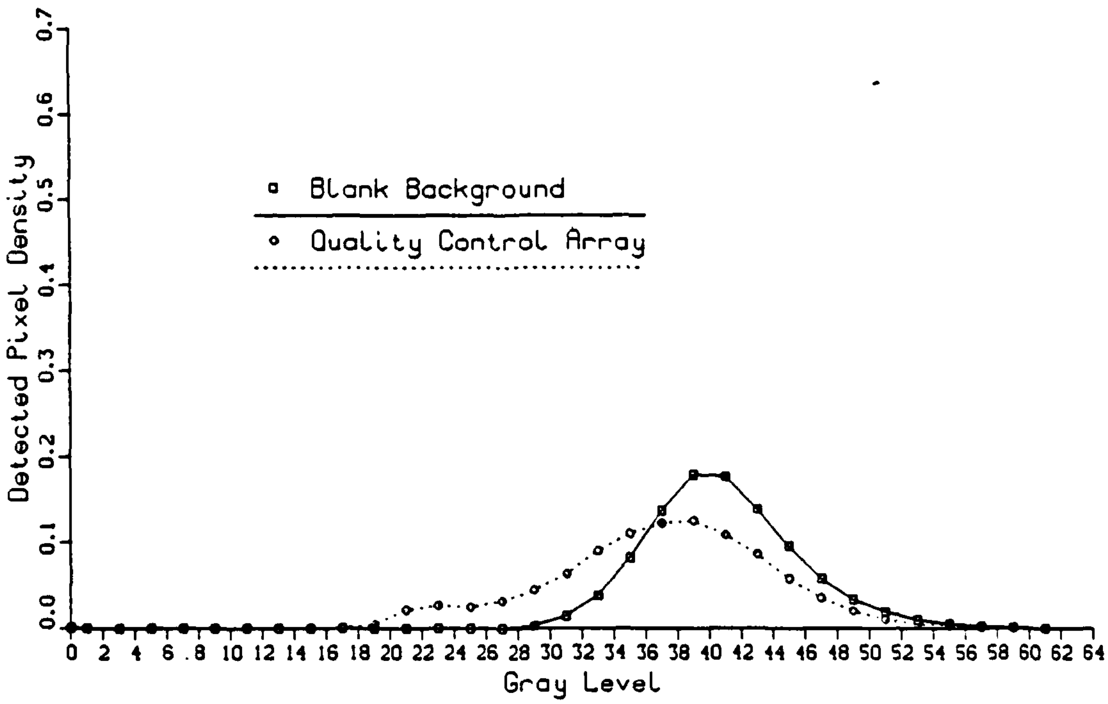


Figure 6.8 Gray Level Distribution of Hologram at PLI x5

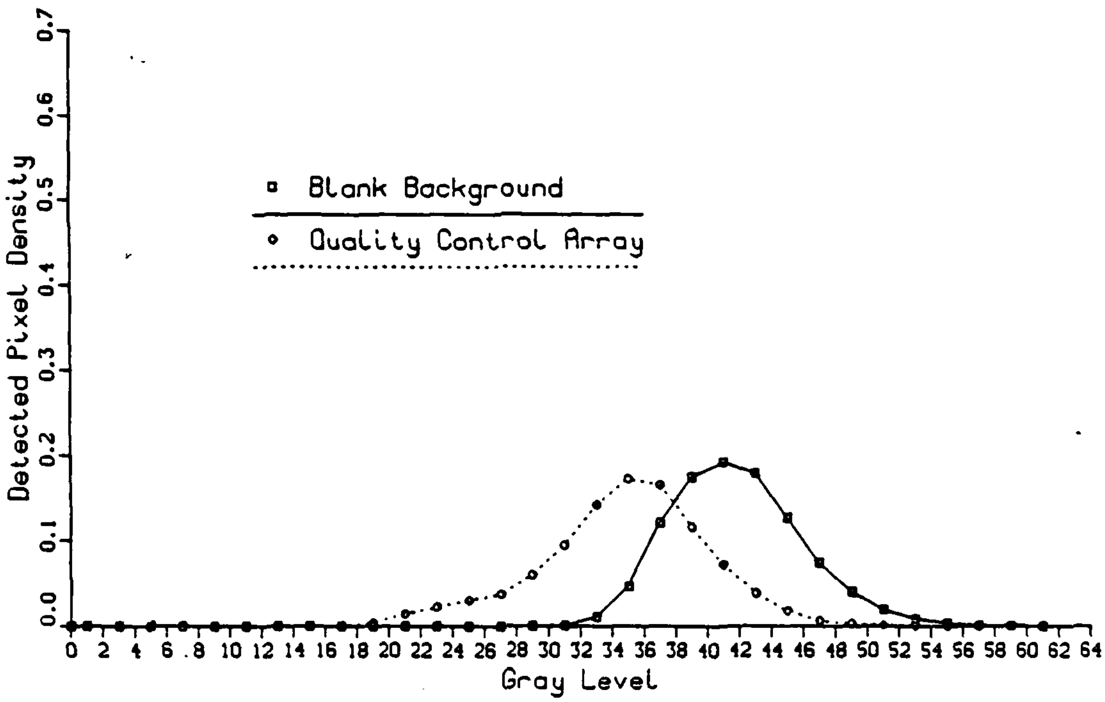


Figure 6.9 Gray Level Distribution of Hologram at PLI x25

C. SUMMARY

The results presented in this chapter have been obtained by using the NPS System 23 in the computer-controlled mode with the Standard Routine. These results demonstrate a portion of the routine's capabilities as well as portray the difficulty in obtaining information from the hologram. Factors responsible for this will be discussed in the final chapter.

VII. CONCLUSIONS

Implementation of computer control for the Quantimet 720 has been accomplished and its performance has been demonstrated by the results presented in Chapter VI. Using the Standard Routine provides a systematic method for quickly obtaining data in a repeatable manner. This is a significant improvement over the manual mode for performing image measurements. The difficulties experienced while achieving the computer interface raise some doubts about the reliability of the Quantimet. The hardware failures have significantly reduced the capabilities of the system. The twisted pair connections that enable flexible module configuration are also a weak point in the system and they should always be checked first when a problem occurs. These problems may be ascribed to the machine's age.

The most important obstacle that remains to acquiring particle information from the hologram is the poor quality of the analog video signal provided to the detector module. There are two contributing causes for this. First is the previously discussed speckle pattern in the hologram. Next is the low fidelity output from the scanner. The video image displayed on the Quantimet is noticeably poorer than the microscopic image of the hologram simultaneously viewed by eye through the binocular eyepiece of the microscope.

This is a result of the scanner's inability to reproduce the hologram. One factor contributing to this is that the spectral content of the hologram does not coincide with the Plumbicon Scanner's peak spectral response. As illustrated in Figure 7.1, the Plumbicon's response for the red lighted hologram is about one fourth of the response for green light.

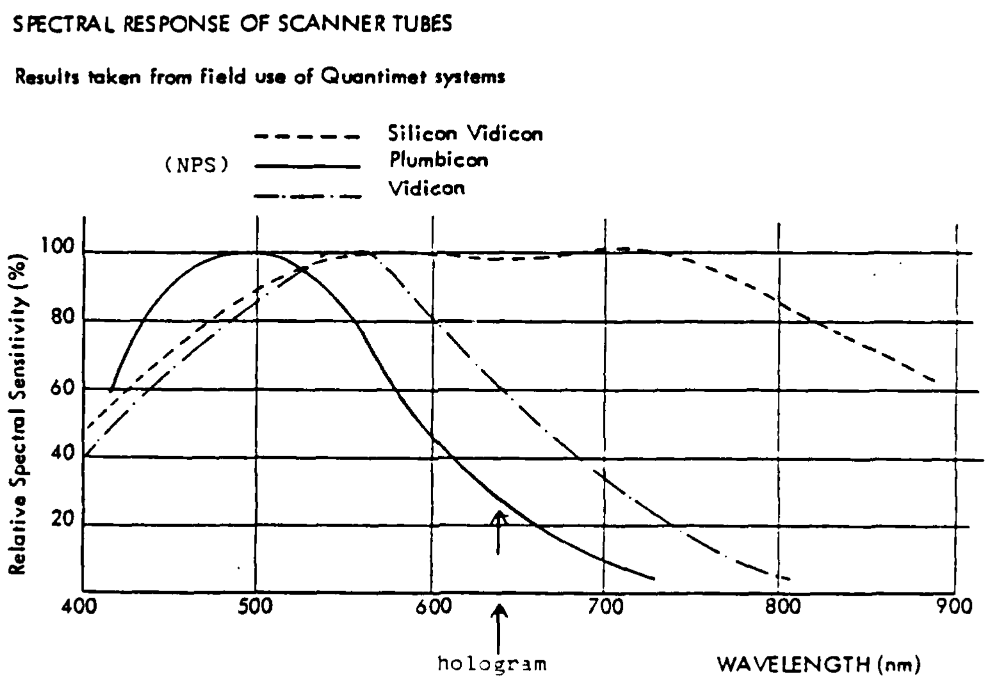


Figure 7.1 Spectral Response of Scanner Tubes [Ref. 5, Figure 4.3]

A more serious concern is the possibility that the scanner tube has lost its sensitivity. Although this is unsubstantiated; previous experience, [Ref. 2], with the NPS scanner and discussions with other users support this position. In those instances, stray ambient light was observed to saturate the scanner output. This does not occur in the NPS system. The presence of ambient light does not have any noticeable effect on the scanner output, and the results obtained for the calibration standard reticle slide required the use of transmitted white light. The end result is that the video image of the hologram is inadequate for use in the 1D Auto Detector.

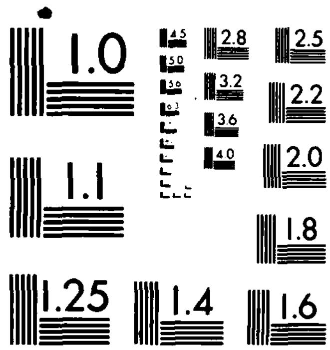
To rectify this, an obvious alternative is to ascertain the operating status of the scanner. This requires technical support from the manufacturer as there is no documentation available for the NPS scanner. If the scanner tube is determined to be defective and is replaced, then it may be possible for the Quantimet 720 to obtain particle information from the hologram. Still, the effects of speckle in the hologram may limit analysis to relatively large particles.

In order to overcome the effects of speckle, digital image processing techniques may be required. However, this technique also requires a high fidelity scanner to provide raw image data.

In summary, this thesis has presented the application of a computer-controlled Quantimet 720 Image Analyser in an effort to obtain particle size information from holograms of rocket engine combustion products. A description of the Quantimet 720 System 23 and the DEC PDP-11 computer that controls it has been included. The process used to resolve the problems with the interface has been described and instructions for using the NPS system have been given. The results that were obtained by using the system to analyze a calibration standard reticle showed that while the NPS computer-controlled Quantimet is capable of producing particle size distributions, it is presently unable to distinguish particles from background in the holographic image. Possible causes for this and their resolution have been addressed.

AD-A161 212 COMPUTER-CONTROLLED IMAGE ANAYSIS OF SOLID PROPELLANT COMBUSTION HOLOGRAMS USING A QUANTIMET 720 AND A PDP-11 (U) NAVAL POSTGRADUATE SCHOOL MONTEREY CA M P SHOOK SEP 85 2/2

UNCLASSIFIED F/G 21/2 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

APPENDIX A

PROCEDURES USED TO OBTAIN PRELIMINARY RESULTS

This appendix comprises two sections. The first describes the procedures used for the reticle slide and the second contains the procedures used for the hologram.

CALIBRATION STANDARD RETICLE

The glass reticle slide was mounted on the Newport Automatic Stage and observed through the Kollsman microscope with a 10x, .25NA, 16mm Baush and Lomb objective using transmitted light through a glass diffusion plate. The diffusion plate was placed on the stage behind the reticle and was used to reduce the intensity of the light and to more evenly illuminate the reticle. The Cole Parmer Model 9741-50 variable intensity lamp with a flexible gooseneck head and a focusing attachment was used as the light source.

The reticle was positioned to focus the quality control array in the center of the field of the microscope. The lamp should be off or as dim as possible to avoid saturating the scanner. The scanner was then coupled to the microscope with the coupler's parfocal adjustment in the maximum forward position. The image was focused and the lamp intensity adjusted to achieve a sensitivity reading of 0.3 to 0.4. The shading corrector was adjusted using the procedure delineated in Reference 8 paragraph 4.6. The range knob position used for this data was 9 o'clock. The blank specimen used to set the shading correction was the blank area between the quality control array and the 8mm reticle.

The detection threshold was selected to provide a detected image for all twenty-three particles in the array with autodelineation on and halo suppression selected.

The chord sizing limits for histogram bins were selected by trial and error to achieve a count of one for each of the twenty-three bins for the quality control array. These limits were then used as a reference for gathering data from the reticle. (See Fig. A.1.)

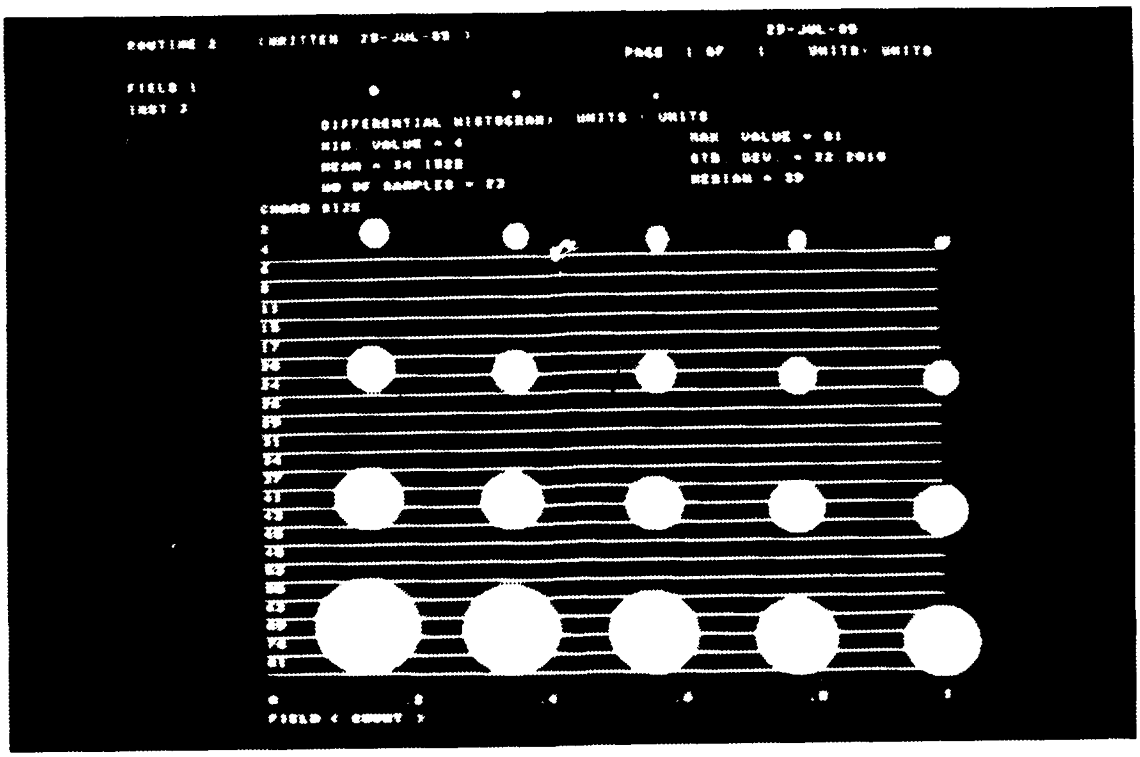


Figure A.1 Display of Quality Control Array Results

The variable frame position was horizontal: 80, vertical: 80. The frame size was horizontal: 720, vertical: 528. This gives a guard region with a width of 80 pixels on all four sides. This should have been larger to allow for overlapped particles.

The sampled area of the reticle was chosen arbitrarily to be across the middle, down one frame then back across. This was empirically determined to be twenty fields each with an area of about 498,775 square microns. These twenty fields yield a sampled area of about twenty percent of the reticle not accounting for circular edges of boundary fields.

The stage step size was empirically determined to be .82 in the horizontal, X, direction and .59 in the vertical, Y, direction. The routine was run, and the stage was manually stepped with the remote stage controller keypad when prompted to do so by the routine.

The routine that was written and used is included as Figure A.2. The actual data obtained from the Quantimet for the quality control array and the reticle are included as Figures A.3 and A.4.

HOLOGRAM

The first step was to present the hologram to the Nikon trinocular microscope for focusing. The technique used was to first focus the stationary mylar disk, and then start the

```
ROUTINE 1
(WRITTEN  29-JUL-85 )                                          29-JUL-85


INST 0 :
CALIBRATION STANDARD RETICLE


INST 1 :
MICROSCOPE :  NON STANDARD TURRET
CALIBRATION:          BIG FRAME  880 * 688 UNITS
                                           ( 1 PP =    1 UNITS )
STAGE STEP SIZE:      MANUAL
NUMBER OF FIELDS:     10 * 2 =20
FOCUS:                MANUAL
FRAME MANUAL


INST 2 :
DETECT :              DARKER THAN   42


INST 3 :
AMEND :               CHORD SIZE 4 UNITS
MEASURE :             FIELD ( COUNT ) DISTRIBUTED BY CHORD SIZE
                                     FROM   2
                                     TO     4
                                     TO     6
                                     TO     8
                                     TO     11
                                     TO     15
                                     TO     17
                                     TO     20
                                     TO     24
                                     TO     26
                                     TO     29
                                     TO     31
                                     TO     34
                                     TO     37
                                     TO     41
                                     TO     43
                                     TO     45
                                     TO     48
                                     TO     53
                                     TO     58
                                     TO     63
                                     TO     69
                                     TO     76
                                     TO     81
```

Figure A.2 Routine 1

```
ROUTINE 1
(WRITTEN  29-JUL-85 )                                          29-JUL-85

                                    PAGE  1 OF   1    UNITS: UNITS

FIELD 1

INST 3

      DIFFERENTIAL HISTOGRAM;  UNITS : UNITS

      MIN. VALUE = 4                        MAX. VALUE = 81

      MEAN = 34.1522                         STD. DEV. = 22.2018

      NO OF SAMPLES = 2                     MEDIAN = 39

CHORD SIZE
    0
2
    0
4
*****************************************************     1
6
*****************************************************     1
8
*****************************************************     1
11
*****************************************************     1
15
*****************************************************     1
17
*****************************************************     1
20
*****************************************************     1
24
*****************************************************     1
26
*****************************************************     1
29
*****************************************************     1
31
*****************************************************     1
34
*****************************************************     1
37
*****************************************************     1
41
*****************************************************     1
43
*****************************************************     1
45
*****************************************************     1
48
*****************************************************     1
53
*****************************************************     1
58
*****************************************************     1
63
*****************************************************     1
69
*****************************************************     1
76
*****************************************************     1
81
*****************************************************     1

FIELD ( COUNT )
```

Figure A.3 Results: Quality Control Array

```
ROUTINE 1
(WRITTEN  29-JUL-85 )   SPECIMEN IDENT =10X2      29-JUL-85
                                         PAGE  1 OF   1    UNITS: UNITS
FIELD 20

INST 3

      DIFFERENTIAL HISTOGRAM:  UNITS : UNITS

      MIN. VALUE = 4                      MAX. VALUE = 81

      MEAN = 18.6955                      STD. DEV. = 14.7584

      NO OF SAMPLES = 1591                MEDIAN = 17.2438

CHORD SIZE
    0
2
    0
4
*********************************    193
6
****************************************    230
8
****************************    164
11
*********************************    192
15
***********************************    203
17
********    44
20
*****************    97
24
******************    102
26
******    32
29
**********    57
31
*****    30
34
*******    40
37
*******    41
41
******    37
43
***    18
45
*****    29
48
**    11
53
****    24
58
***    16
63
**    13
69
    1
76
**    14
81
*    3


FIELD ( COUNT )
```

Figure A.4 Results: Reticle

disk spinning and present the hologram. Because it is relatively difficult to accurately position the hologram, low power objectives were used to initially locate and focus the image. Then the focusing procedure was iterated using higher power objectives until the desired magnification was achieved. The 10x, 25NA objective was used to obtain the results. The laser power setting used was 0.5 watt. Increasing the power level to 0.6 or 0.7 watt provides a brighter image, but the laser would not maintain the higher power setting long enough to obtain data.

Once the image is focused through the binocular eyepiece the next step was to couple the scanner to the photo tube of the microscope. Some "rigging" was necessary to accomplish this because the scanner must be physically supported to align with the photo tube. The scanner coupler's parfocal adjustment was set to give a reasonably good focus on the Quantimet image display when the hologram was in focus through the binocular eyepiece. This caused a slight reduction in the Quantimet's video frame size on the right corners of the display. Once the video image was displayed, focusing adjustments were made with the motorized stage. Focusing was difficult because of the low contrast video image that was displayed. Increasing the Plumbicon Light Integration to x5 brightened the image, but the resulting slower display rates aggravated the focusing process.

Many attempts were made to achieve a video signal that would give a usable detected image, but they were unsuccessful. As a result of this phenomenon, routines were written to portray the detection problem by obtaining a gray level distribution of the image. These routines and their outputs, which include all pertinent System 23 settings, are included as Figures A.5 through A.13.

```
ROUTINE 2
(WRITTEN  26-AUG-85 )                                        16-SEP-85


INST 0 :
CALIBRATION STANDARD RETICLE


INST 1 :
MICROSCOPE :  NON STANDARD TURRET
CALIBRATION:          BIG FRAME  880 * 688 UNITS
                                              ( 1 PP =   1 UNITS )
NIKON MICROSCOPE OBJECTIVE:  X10

PLUMBICON LIGHT INTEGRATION:  X1
WHITE LEVEL:  1.0
SENSITIVITY:  0.32

LIVE FRAME POSITION:  H=250  V=200
...............SIZE:  H=400  V=300

SHADING RANGE:  9 O'CLOCK

STAGE STEP SIZE:     MANUAL
NUMBER OF FIELDS:    1 * 1 =1
FOCUS:               MANUAL
FRAME MANUAL


INST 2 :
DETECT :             DARKER THAN   0
ATTENUATION:  DETAIL


INST 3 :
DETECT :             DARKER THAN   1
MEASURE :            FIELD AREA DISTRIBUTED BY DETECT LIGHT
                                          TO    1
                                          TO    61
                                            STD 30


INST 4 :
PRINT :              INST 0
PRINT :              INST 1
PRINT :              INST 2
PRINT :              INST 3
```

Figure A.5 Routine 2

```
ROUTINE 2
(WRITTEN  26-AUG-85 )   SPECIMEN IDENT =BLANK      26-AUG-85
                                      PAGE  1 OF   1    UNITS: UNITS
FIELD 1

INST 3

     DIFFERENTIAL HISTOGRAM:  UNITS : UNITS

     MIN. VALUE = 53                          MAX. VALUE = 59

     MEAN = 56.4803                           STD. DEV. = 1.01947

     NO OF SAMPLES = 122328                   MEDIAN = 58.9751

DETECT LIGHT
    0
1
    0
3
    0
5
    0
7
    0
9
    0
11
    0
13
    0
15
    0
17
    0
19
    0
21
    0
23
    0
25
    0
27
    0
29
    0
31
    0
33
    0
35
    0
37
    0
39
    0
41
    0
43
    0
45
    0
47
    0
49
    0
51
    0
53
   523
55
***********************************************    61407
57
**********************************************    60316
59
    82
61
    0

FIELD AREA    PRINT
```

Figure A.6 Results: Reticle, Blank

```
ROUTINE 2
(WRITTEN  26-AUG-85 )    SPECIMEN IDENT =QC ARRAY  26-AUG-85
                                        PAGE  1 OF   1    UNITS: UNITS
FIELD 1

INST 3

      DIFFERENTIAL HISTOGRAM:  UNITS : UNITS

      MIN. VALUE = 5                    MAX. VALUE = 57

      MEAN = 46.896                     STD. DEV. = 14.6703

      NO OF SAMPLES = 120813            MEDIAN = 55.6334

DETECT LIGHT
    0
1
    0
3
    0
5
*    1138
7
*****    7658
9
*    1897
11
*    1027
13
    755
15
    649
17
    598
19
    568
21
    563
23
    508
25
    517
27
    533
29
    539
31
    543
33
    544
35
    545
37
    588
39
    608
41
    618
43
    681
45
*    860
47
*    1131
49
*    1719
51
*******    10385
53
*****************************************************    79679
55
****    5940
57
    22
59
    0
61
    0


FIELD AREA    PRINT
```

Figure A.7 Results: Reticle, Quality Control Array

```
ROUTINE 3
(WRITTEN  26-AUG-85 )                                              16-SEP-85


INST 0 :
CALIBRATION STANDARD RETICLE
HOLOGRAM NO. 303


INST 1 :
MICROSCOPE :  NON STANDARD TURRET
CALIBRATION:          BIG FRAME  880 * 688 UNITS
                                             ( 1 PP =   1 UNITS )

NIKON MICROSCOPE OBJECTIVE:  X10
LASER POWER:  .5 WATT

PLUMBICON LIGHT INTEGRATION:  X5
WHITE LEVEL:  1.0
SENSITIVITY:  0.65

LIVE FRAME POSITION:  H=250  V=200
...............SIZE:  H=400  V=300

SHADING RANGE:  9 O'CLOCK

STAGE STEP SIZE:     MANUAL
NUMBER OF FIELDS:    1 * 1 =1
FOCUS:               MANUAL
FRAME MANUAL


INST 2 :
DETECT :             DARKER THAN   0
ATTENUATION:  DETAIL


INST 3 :
DETECT :             DARKER THAN   1
MEASURE :            FIELD AREA DISTRIBUTED BY DETECT LIGHT
                                          TO    1
                                          TO    61
                                            STD 30


INST 4 :
PRINT :              INST 0
PRINT :              INST 1
PRINT :              INST 2
PRINT :              INST 3
```

Figure A.8 Routine 3

```
ROUTINE 3
(WRITTEN  26-AUG-85 )   SPECIMEN IDENT =BLANK     26-AUG-85
                                      PAGE  1 OF   1    UNITS: UNITS

FIELD 1

INST 3

      DIFFERENTIAL HISTOGRAM:  UNITS : UNITS

      MIN. VALUE = 49                    MAX. VALUE = 61

      MEAN = 41.287                      STD. DEV. = 4.99131

      NO OF SAMPLES = 123546             MEDIAN = 43.4899

DETECT LIGHT
    104
1
    2
3
    5
5
    7
7
    0
9
    3
11
    2
13
    1
15
    4
17
    6
19
    1
21
    10
23
    10
25
    9
27
    22
29
*    426
31
***    1804
33
********    4783
35
******************    10187
37
******************************    16959
39
****************************************    22080
41
****************************************    21832
43
*******************************    17161
45
*********************    11820
47
************    7173
49
*******    4116
51
****    2423
53
**    1260
55
*    726
57
*    399
59
    162
61
    49


 FIELD AREA    PRINT
```

Figure A.9 Results: Hologram, Blank, PLI x5

```
ROUTINE 3
(WRITTEN  26-AUG-85 )   SPECIMEN IDENT =QC ARRAY  26-AUG-85
                                          PAGE  1 OF   1    UNITS: UNITS

FIELD 1

INST 3

        DIFFERENTIAL HISTOGRAM:  UNITS : UNITS

        MIN. VALUE = 1                          MAX. VALUE = 61

        MEAN = 37.3043                          STD. DEV. = 6.91523

        NO OF SAMPLES = 119969                  MEDIAN = 40.2812

DETECT LIGHT
     0
1
     1
3
     4
5
     1
7
     4
9
     10
11
     20
13
     10
15
     8
17
     130
19
*    559
21
*******    2618
23
********    3232
25
********    2978
27
**********    3866
29
**************    5378
31
********************    7626
33
****************************    10877
35
**********************************    13230
37
**************************************    14725
39
***************************************    15054
41
**********************************    13075
43
***************************    10385
45
******************    6948
47
***********    4250
49
******    2464
51
***    1292
53
**    682
55
*    340
57
    138
59
    53
61
    11


FIELD AREA    PRINT
```

Figure A.10 Results: Hologram, QC Array, PLI x5

```
ROUTINE 4
(WRITTEN  26-AUG-85 )                                          16-SEP-85


INST 0 :
CALIBRATION STANDARD RETICLE
HOLOGRAM NO. 303


INST 1 :
MICROSCOPE :  NON STANDARD TURRET
CALIBRATION:          BIG FRAME  880 * 688 UNITS
                                                ( 1 PP =   1 UNITS )
NIKON MICROSCOPE OBJECTIVE:  X10
LASER POWER:  .5 WATT

PLUMBICON LIGHT INTEGRATION:  X25
WHITE LEVEL:  1.0
SENSITIVITY:  0.28

LIVE FRAME POSITION:  H=250  V=200
...............SIZE:  H=400  V=300

SHADING RANGE:  9 O'CLOCK

STAGE STEP SIZE:     MANUAL
NUMBER OF FIELDS:    1 * 1 =1
FOCUS:               MANUAL
FRAME MANUAL


INST 2 :
DETECT :             DARKER THAN   0
ATTENUATION:  DETAIL


INST 3 :
DETECT :             DARKER THAN   1
MEASURE :            FIELD AREA DISTRIBUTED BY DETECT LIGHT
                                          TO     1
                                          TO     61
                                            STD 30


INST 4 :
PRINT :              INST 0
PRINT :              INST 1
PRINT :              INST 2
PRINT :              INST 3
```

Figure A.11 Routine 4

```
ROUTINE 4
(WRITTEN  26-AUG-85 )   SPECIMEN IDENT =BLANK     26-AUG-85
                                       PAGE  1 OF   1    UNITS! UNITS

FIELD 1

INST 3

     DIFFERENTIAL HISTOGRAM!  UNITS ! UNITS

     MIN. VALUE = 1                    MAX. VALUE = 61

     MEAN = 42.2641                    STD. DEV. = 4.23976

     NO OF SAMPLES = 118057            MEDIAN = 44.5084

DETECT LIGHT
    0
1
    7
3
    4
5
    1
7
    6
9
    5
11
    3
13
    7
15
    8
17
    2
19
    1
21
    5
23
    6
25
    10
27
    10
29
    8
31
    146
33
**    1270
35
**********    5518
37
*************************    14323
39
************************************    20593
41
***************************************    22667
43
*************************************    21082
45
**************************    14926
47
***************    8732
49
********    4689
51
****    2297
53
**    1041
55
*    418
57
    156
59
    78
61
    38


FIELD AREA    PRINT
```

Figure A.12 Results: Hologram, Blank, PLI x25

```
ROUTINE 4
(WRITTEN  26-AUG-85 )   SPECIMEN IDENT =QC ARRAY  26-AUG-85
                                 PAGE  1 OF   1    UNITS: UNITS

FIELD 1

INST 3

      DIFFERENTIAL HISTOGRAM:  UNITS : UNITS

      MIN. VALUE = 1                         MAX. VALUE = 61

      MEAN = 35.2154                         STD. DEV. = 5.35139

      NO OF SAMPLES = 114542                 MEDIAN = 38.0924

DETECT LIGHT
    0
1
    2
3
    0
5
    0
7
    2
9
    2
11
    1
13
    0
15
    3
17
    6
19
*    485
21
****    1641
23
*******    2568
25
*********    3490
27
***********    4308
29
******************    6841
31
****************************    10861
33
******************************************    16268
35
****************************************************    19760
37
*************************************************    18926
39
***********************************    13272
41
*********************    8262
43
***********    4378
45
*****    2022
47
**    744
49
*    341
51
   177
53
   113
55
   46
57
   12
59
   10
61
   1


FIELD AREA    PRINT
```

Figure A.13 Results: Hologram, QC Array, PLI x25

APPENDIX B

USE OF THE LIGHT PEN MODULE

The procedures contained in this appendix apply to use of the Light Pen with the Quantimet in manual mode. No attempt was made to use the pen with the computer-controlled mode.

The Light Pen in the NPS system is wired to work in conjunction with the 1D Auto Detector, the MS3 Standard Analyser, the Function Computer, and the Classifier Collector.

The switch positions below are specifically required for light Pen use:

MODULE Switches	POSITION
DISPLAY	
Detected	Up
Scale and Figs	Center or Up
1D AUTO DETECTOR	
Display	Up
MS3	
Key 2	Up
Function	Pattern Recognition
Function Computer	
Function	Not Volume
Classifier-Controller	
Function	Function 1
CIF	Off

Other switches on these modules may be set as desired and will affect the measurement value, so care must be taken to explicitly set the switches to the desired position in order to avoid obtaining confusing results. Safe positions for initial measurements are indicated below:

MODULE Switches	POSITION
SYSTEM CONTROL	
Accumulator (Acc)	Down
System Mode	
Avg	Down
Intercept - Area	Down (Area)
Continuous-Single Scan/Auto	Up (Continuous)
DISPLAY	
Computed	Up
Guard	Up
Scale&Figs	Center
1D	As necessary to obtain detected image
MS3	
Input	Normal
Sizer	Down
>/<=	Up (>)
Key 1	Up
Count	Full
Display	Up
FUNCTION COMPUTER	
Input	Normal
CLASSIFIER	
Sizer	Off
Display	Down
COLLECTOR	
Divider	1
Display	Down

The following criteria must be met in order to use the Light Pen:

* Proper setting of the switches as listed above.

* A detected image with distinct features. These are identified by a flag at their ACP placed there by the MS3. Only features flagged by the MS3 can be selected by the Light Pen.

* A visible Light Pen Cursor. The visibility of the cursor is controlled by the detected contrast knob on the Display module.

The procedures for using the Light Pen is as follows.

- Establish the detected image and any desired sizing criteria to distinguish desired features.

- Withdraw the Light Pen from its holder; now all data transferred to the Function Computer is only that selected by the Light Pen. The push button below the pen's hole may be pressed to select all features. The other push button serves no purpose in the NPS system.

- To select the desired feature for measurement, point the Light Pen at it so that the cursor intercepts the feature. The measurement value is displayed in the upper lefthand display according to the collector divider setting.

APPENDIX C

DEVELOPING FORTRAN PROGRAMS

This appendix includes the procedures needed to compile, link, and run FORTRAN programs for use with the NPS Quantimet 720.

COMPILATION

The NPS PDP-11/04 requires threaded compiler code. The compiler has been built to provide this by default. This type of code is required because only standard arithmetic hardware is included with the computer. The issue of type of code produced by the compiler arose when trying to compile the programs on a remote PDP-11/34 and then run them on the PDP-11/04 connected to the Quantimet. The PDP-11/34 has additional arithmetic hardware and its compiler produced in-line code, which was incompatible with the PDP-11/04. Threaded code is accepted by both machines.

Another consequence of threaded code is that it requires a different FORTRAN library subroutine file than the in-line code does. So, the systems library, SYSLIB.OBJ, was rebuilt to include the threaded code library functions.

The files necessary to compile the FORTRAN program are FORTRA.SAV and SYSLIB.OBJ.

The command sequence to compile the program is indicated below:

```
.FORTRAN<RET>
files? FILENAME/[options]
```

The NO SWAP option is recommended by the QLINK documentation.

LINKING

The object file produced by the compiler must be linked to the appropriate QLINK library to run on the Quantimet. The two libraries that apply to the NPS system are QLIBDC.OBJ and QLNBDC.OBJ. The QLI--- library includes parameter passing checks and the QLN--- does not. The QLIBDC library should be used until an error-free program is developed.

The procedure for linking this library to the FORTRAN program is listed below:

```
  .RLINK <RET>
  *FILENAME = FILENAME, QLIBDC/I <RET>
Library Search? QSY23C<RET>
Library Search? DCIF<RET>
Library Search? SQABT<RET>
Library Search? <RET>
  *<CNTRL C>
```

The '/I' after QLIBDC indicates that specific modules are to be Included in the linking process.

QSY23C specifies the module for System 23C. DCIF indicates there is no Interactive Interface module, and $QABT handles error reporting.

RUNNING

To run the program enter .R FILENAME. Additional information is contained in References 6, 20, and 23.

APPENDIX D

NPS SYSTEM 23C CONFIGURATION STATUS

This appendix contains output from the System 23 CONFIG program which defines the initial calibration settings. Figure D.1 contains the Calibration Summary, Figure D.2 contains the questions asked by the Alter option, and Figure D.3 is the Help option narrative. The configuration status consists of seventeen items, but only a portion of these are applicable to the NPS system. The information contained in the status is used by the Standard Routine by default. The status may be changed while in the Standard Routine by entering its Calibration mode. The following is a discussion of the settings as they apply to the NPS system. The numbering and categories correspond to those in the Figures.

1) & 2) Second Peripheral. The standard System 23 has provision for two input peripherals via a scanner changeover unit. This doesn't apply to the NPS system. The primary peripheral is assumed to be a microscope that has a turret and magnification changers that can be controlled by the keyboard. This doesn't apply either.

3) Densitometer. There is none in the NPS system.

4) Function Analyser. There is only one Function Computer in the NPS system. Note: The terms, Analyser and Computer are used interchangeably in the documentation.

5) Amender. There is none in the NPS system

6) Features/Scan. This defines the maximum number of features that will be used in a single measurement scan. Their ACPs are counted sequentially as the scan moves through the live frame. This can be changed but a number larger than 200 might require larger buffer space. This was not investigated.

7) Transmission or Incident Optics. This applies to standard peripherals and is not applicable to the NPS system.

8) Turret Settings. These apply to standard peripherals and is not applicable.

9) Auto-Focus Settings. Not applicable to NPS system.

10) Stage Step Size. Not applicable to NPS system.

11) TTY line length. Set for paper width: 80 or 132.

12) Form Feed on TTY. The LA36 DECWRITER recognizes the form feed character.

13) Coordinate Transform module. Not present.

14) & 15) Ferets. Four are available: 0,45,90,135 degrees.

16) Turret. The turret in the NPS system is not the standard System 23 turret. Using the non-standard option excludes irrelevant information from Instruction 1 of the Standard Routine.

17) Detector. The NPS system has a detector.

```
 R CONFIG
ENTER REQUIRED ACTION
HELP,SUMMARY,ALTER OR END
?S

                   *** CALIBRATION SUMMARY ***

ITEM
 1)   SECOND PERIPHERAL : NONE
 2)   SECOND PERIPHERAL CANNOT STEP
 3)   DENSITOMETER NOT PRESENT
 4)   1 FUNCTION ANALYSERS
 5)   0 AMENDERS
 6)   200 FEATURES / SCAN
 7)   TRANSMISSION OPTICS

      MICROSCOPE OBJECTIVE MAGNIFICATONS
      STARTING WITH THE TURRET POSITION CURRENTLY SELECTED
      READING ANTI-CLOCKWIZE FROM ABOVE

TURRET POSITION NOT PROPERLY ENGAGED
8.1)  X32
8.2)  X100
8.3)  X63
8.4)  X3.2
8.5)  X12.5
8.6)  X6.3

      AUTO-FOCUS STEP SIZES
                 MAG-CHANGER SETTINGS
     OBJECTIVE    X1.0    X1.2    X0.8
9.1)  X32         0.1     0.1     0.1
9.2)  X100        0.1     0.1     0.1
9.3)  X63         0.1     0.1     0.1
9.4)  X3.2        0.1     0.1     0.1
9.5)  X12.5       0.1     0.1     0.1
9.6)  X6.3        0.1     0.1     0.1

10) 0 MICRON STAGE STEP SIZE
11)  TTY LINE LENGTH : 80 CH
12)  FORM FEED ON TTY
13)  CO-ORDINATE TRANSFORM MODULE NOT PRESENT
14)  NUMBER OF FERETS FOR LENGTH= 4

15)   NUMBER OF FERETS FOR BREADTH= 4

16) NON STANDARD TURRET
17) DETECTOR PRESENT
ENTER REQUIRED ACTION
HELP,SUMMARY,ALTER OR END
?A
```

Figure D.1 Calibration Summary

```
ENTER ITEM TO BE CHANGED
ITEM? 1
ENTER NAME OF SECOND PERIPHERAL (<15 CHARS)
?

CAN SECOND PERIPHERAL STEP? (Y OR N)

IS A DENSITOMETER IN THE SYSTEM? (Y OR N)

HOW MANY FUNCTION ANALYSERS? (1-4)

HOW MANY AMENDERS? (0,1, OR 2)

HOW MANY FEATURES / SCAN?

IS MICROSCOPE TRANSMISSION? (Y OR N)

TURRET POSITION NOT PROPERLY ENGAGED
8.1) CHANGE OBJECTIVE FROM : 32   TO?
TURRET POSITION NOT PROPERLY ENGAGED
8.2) CHANGE OBJECTIVE FROM : 100  TO?
TURRET POSITION NOT PROPERLY ENGAGED
8.3) CHANGE OBJECTIVE FROM : 63   TO?
TURRET POSITION NOT PROPERLY ENGAGED
8.4) CHANGE OBJECTIVE FROM : 3.2  TO?
TURRET POSITION NOT PROPERLY ENGAGED
8.5) CHANGE OBJECTIVE FROM : 12.5 TO?
TURRET POSITION NOT PROPERLY ENGAGED
8.6) CHANGE OBJECTIVE FROM : 6.3  TO?

ENTER FOCUS STEP SIZES
0.1,0.2,0.4,0.8,1.6,3.2,6.4 OR 12.7 ALLOWED

9.1)  X32      OBJECTIVE
FOR MAG X1.0?
FOR MAG X1.2?
FOR MAG X0.8?

9.2)  X100     OBJECTIVE
FOR MAG X1.0?
FOR MAG X1.2?
FOR MAG X0.8?

9.3)  X63      OBJECTIVE
FOR MAG X1.0?
FOR MAG X1.2?
FOR MAG X0.8?

9.4)  X3.2     OBJECTIVE
FOR MAG X1.0?
FOR MAG X1.2?
FOR MAG X0.8?

9.5)  X12.5    OBJECTIVE
FOR MAG X1.0?
FOR MAG X1.2?
FOR MAG X0.8?

9.6)  X6.3     OBJECTIVE
FOR MAG X1.0?
FOR MAG X1.2?
FOR MAG X0.8?

WHAT IS THE STAGE STEP SIZE?

IS TTY LINE SHORT? (Y OR N)

FORM FEED ON TTY? (Y OR N)

IS A CO-ORDINATE TRANSFORM MODULE IN THE SYSTEM? (Y OR N)

14)  NUMBER OF FERETS FOR LENGTH=

15)   NUMBER OF FERETS FOR BREADTH=

NON STANDARD TURRET? (Y OR N)

IS A DETECTOR IN THE SYSTEM? (Y OR N)
```

Figure D.2 Alter Option

```
ENTER ITEM TO BE CHANGED
ITEM? H
ENTER REQUIRED ACTION
HELP,SUMMARY,ALTER OR END
?H

SETTING OF INITIAL CALIBRATION.

THE CALIBRATIONS ARE HELD IN A FILE, AND A SUMMARY OF THEM CAN BE
OBTAINED ON REQUEST.

EACH SETTING IS ITEMIZED IN THE SUMMARY,AND IF CHANGES ARE REQUIRED
IN ANY ITEM, ITS IDENTIFICATION SHOULD BE ENTERED.

IF AN ENTRY IS TERMINATED BY 'LINE FEED' THEN THE NEXT ITEM WILL
BE SELECTED FOR ALTERATION;
IF TERMINATED BY 'RETURN' THEN AN IDENTIFICATION WILL BE REQUESTED.

IF NO UPDATING VALUE IS ENTERED (I.E. ONLY  'LINE FEED' OR 'RETURN')
THEN THE SETTING WILL REMAIN UNCHANGED.

TWO SETS OF OBJECTIVE MAGNIFICATIONS AND FOCUS STEP SIZES ARE
HELD, ONE FOR TRANSMISSION OPTICS AND ONE FOR INCIDENT OPTICS
IF A MICROSCOPE WITH BOTH IS IN USE, THEN FIRST ONE TYPE (INC OR TRANS)
SHOULD BE SELECTED AND SET UP, AND THEN THE TYPE
SHOULD BE CHANGED, AND THE OTHER SET UP
    WHERE A TURRET IS USED WHICH HAS MORE THAN 6 OBJECTIVES
   IT MAY BE DECLARED 'NON STANDARD' WHICH OMITS REFERENCE
TO OBJECTIVE AND MAG CHANGER POSITIONS IN THE SYSTEM 23

AN ITEM NUMBER OF 0 TERMINATES THE UPDATING.


ENTER REQUIRED ACTION
HELP,SUMMARY,ALTER OR END
?E
```

Figure D.3 Help Option

APPENDIX E

PRESENT STATUS OF THE SYSTEM 23C

This appendix contains information pertaining to the condition of the Quantimet 720 modules at the time of this writing. Overall, the system is capable of running in the computer-controlled mode; but, it can only perform a portion of its measurements because of hardware failures. These failures affect the following categories of image analysis tasks. The system cannot perform any feature measurements, full feature count, or image transfer.

Discrepancies that have been observed are listed below:

Scanner - The scanner tube is suspected of having lost its sensitivity; this requires manufacturer's support to confirm.

MS3 - Full feature count gives wrong results.

Collector - Collector display switch trashes the computed display when enabled.

Function Computer - removed, and sent to manufacturer for repair because all feature measurements were extraordinarily large.

LA36 Decwriter - occasionally quits functioning, in both local and line modes.

The Function Computer's daisy chain connections have been bypassed to provide continuity in the signal paths. Other connections are hanging free. The absence of this module is responsible for causing the most significant degradation of system capability. This limits the measurements that can be accomplished to field data only. However, this was adequate for obtaining the results included in Chapter VI.

APPENDIX F

NPS QUANTIMET 720 SYSTEM 23 WIRELIST

This appendix contains a revised wiring list for the NPS System 23 based on the one contained in Appendix B of Reference 2. The revision primarily reflects those changes necessary to accomplish the computer-controlled operation. The format has also been changed to distinguish between the logical categories of connections described in Section II C and to be consistent with the manufacturer's technical data sheets contained in Reference 4.

The majority of connections are made with twisted pair wires: one green wire and one of a different color. The modules' twisted pair connections consist of sockets which designate output signals, and plugs which designate inputs. Other common connectors are the 6-way programmer cables which link the Control Interface module to the other modules. The COMMENTS column of the wire list indicates what kind of connector is used, if it is not a twisted pair. Also, the plug and socket connector is indicated. The numbering of connections has been retained from Reference 2 to provide for traceability between the two wire lists.

The abbreviations used in the wirelist for the modules are listed below.

Abbreviation	Module
1D	1D Auto Detector
CC	Classifier-Collector
CIF	Control Interface
DPLY	Display
FC	Function Computer
FIFI	Field/Image/Feature Interface
LP	Light Pen
MK1	MK1 Frame Smasher
MS3	MS3 Standard Analyser
SYS	System Control
VFS	Variable Frame and Scale

#	P/S	Name	Module	#	Name	Comments
HIGH LEVEL PROGRAMMING CONNECTIONS						
1	S	DETECTED VIDEO OUT SELECTED	LP	7	DETECTED VIDEO IN (L)	
2	S	DETECTED VIDEO OUT 1				
3	S	DETECTED VIDEO OUT 2				
4	S	DETECTED VIDEO OUT 3				
5	S	UNDETECTED SELECTED				
6	P	TRANSITION FROM 1				
7	P	TRANSITION FROM 2				
8	P	TRANSITION FROM 3				
9	P	TRANSITION FROM ALL	1D		REFERENCE PHASE	
10	P	BLANK FRAME IN (L)	MK1	10	O/P	
11	S	BLANK FRAME IN (R)	TERMINATED			
12	P	DATA OUT SELECTED (L)				
13	S	DATA OUT SELECTED (R)	MS3	26	FUNCTIONS DATA IN SELECTED	
14	S	DATA OUT 1				
15	S	DATA OUT 2				
16	S	DATA OUT 3				
17	S	CONTIGUITY OUT				
18	S	CONTIGUITY KEY				
	S	REFERENCE PHASE	1D	9	TRANSITION FROM ALL	FLYING LEAD
19	P	BIG FRAME IN (L)	MK1	8	FRAME 2 (R)	
20	S	BIG FRAME IN (R)	DPLY	2	BLANK FRAME IN	
CONTROL INTERFACE CONNECTIONS						
31	S	PROGRAMMER CONTROLS	CIF	1	A DETECTOR	6 WAY
29	P	DETECTED	CIF	2	A-1	
30	P	UNDETECTED	CIF	3	A-32	
33	P	LOAD A	CIF	25	I-2	(1)
34	P	LOAD B	CIF	25	I-4	(1)
32	P	INSERT FOR 6 BIT	CIF	25	I-8	(1)
26	P	INSERT FOR KEYBOARD	CIF	37	K-32	

(1) These twisted pairs form a 6 way cable.

#	P/S	Name	Module	#	Name	Comments
STANDARD REAR CONNECTIONS						
21	P	BV FRAME (L)	SYS	25	BV FRAME	
22	S	BV FRAME (R)	VFS	9	BV FRAME (L)	
23	P	SYNC (L)	SYS	21	SYNC	
24	S	SYNC (R)	VFS	15	SYNC (L)	
25	S	DIGITISED VIDEO	FIFI	10	IMAGE DIGITISED IN	20 WAY
27	P	PK WHITE (L)	SYS	26	PK WHITE	
28	S	PK WHITE (R)				
35	P	CLOCK (L)	SYS	32	CLOCK (R)	
36	S	CLOCK (R)	TERMINATED			
37	P	INTAR (L)				
38	S	INTAR (R)				
39	P	DETECTED DISPLAY (L)	LP	12	DETECTED DISPLAY (R)	
40	S	DETECTED DISPLAY (R)	DPLY	7	DETECTED DISPLAY	
41	S	SCANNER VIDEO	SYS	35	SCANNER VIDEO (L)	BNC
42	S	AUX VIDEO				BNC
43	S	DISPLAY VIDEO	DPLY	12	DISPLAY	BNC

CLASSIFIER COLLECTOR (CC)

#	P/S	Name	Module	#	Name	Comments
CLASSIFIER HIGH LEVEL PROGRAMMING CONNECTIONS						
1	P	CLASSIFIER FUNCTION IN (L)	FC	2	FUNCTION OUT	20 WAY
2	S	CLASSIFIER FUNCTION IN (R)	CC	7	COLLECTOR FUNCTION 1 (L)	20 WAY
3	S	CLASSIFIER OUTPUT 1				
4	S	CLASSIFIER OUTPUT 2				
5	S	CLASSIFIER OUTPUT 3				
6	S	CLASSIFIER OUTPUT SELECTED	CC	15	COLLECTOR GATE IN 4 (L)	
COLLECTOR HIGH LEVEL PROGRAMMING CONNECTIONS						
7	P	COLLECTOR FUNCTION 1 IN (L)	CC	2	CLASSIFIER FUNCTION IN (R)	20 WAY
8	S	COLLECTOR FUNCTION 1 IN (R)	FIFI	13	FEATURE FUNCTION IN (T)	20 WAY
P		COLLECTOR FUNCTION 2 IN (L)				20 WAY
S		COLLECTOR FUNCTION 2 IN (R)				20 WAY
9	P	COLLECTOR GATE IN 1 (L)	MS3	34	COUNT TO COLL GATE	
10	S	COLLECTOR GATE IN 1 (R)				
11	P	COLLECTOR GATE IN 2 (L)				
12	S	COLLECTOR GATE IN 2 (R)				
13	P	COLLECTOR GATE IN 3 (L)	FIFI	22	FIFI GATE OUT	
14	S	COLLECTOR GATE IN 3 (R)				
15	P	COLLECTOR GATE IN 4 (L)	CC	6	CLASSIFIER OUTPUT SELECTED	
16	S	COLLECTOR GATE IN 4 (R)				
17	P	COLLECTOR GATE IN 5 (L)				
18	S	COLLECTOR GATE IN 5 (R)				
19	S	COLLECTED KEY OUT				
20	S	COLLECTED GATE OUT				
21	S	FUNCTIONS FUNCTION OUT				
22	S	FUNCTIONS COLLECT OUT	FIFI	19	COLLECT OUT (L)	
23	P	FUNCTIONS DATA IN	MS3	27	FUNCTIONS SELECTED	
24	S	FUNCTIONS SELECTED	FIFI	4	FIELD DATA IN (T)	
CONTROL INTERFACE CONNECTIONS						
33	S	PROGRAMMER CONTROL COLLECTOR	CIF	13	E COLLECTOR	6 WAY
34	P	PRGRMMR CONTROL CLASSIFIER (L)	CIF	72	W CLASS SELECT	
35	S	PRGRMMR CONTROL CLASSIFIER (R)				
47	P	SIZE DISTRIBUTOR	CIF	82	Q CLASSIFIER	32 WAY

CLASSIFIER COLLECTOR (CC)

#	P/S	Name	Module	#	Name
STANDARD REAR CONNECTIONS					
25	P	V TRIG (L)	VFS	12	V TRIG (R)
26	S	V TRIG (R)			
27	P	CLOCK (L)	MS3	36	CLOCK (R)
28	S	CLOCK (R)	FIFI	45	CLOCK (L)
29	P	HOLD (L)	CIF	76	COLL HOLD
30	S	HOLD (R)			
31	P	DIVIDE BY 16 (L)			
32	S	DIVIDE BY 16 (R)	TERMINATED		
	P	RESET (L)			
	S	RESET (R)			
36	P	COMPUTER DISPLAY (L)	FIFI	55	COMPUTER DISPLAY (R)
37	S	COMPUTER DISPLAY (R)	FC	13	COMPUTER DISPLAY (L)
38	P	FAIL (L)	MS3	50	FAIL
39	S	FAIL (R)			
40	P	WAIT			
41	S	FINISH	FIFI	21	FINISH FROM COLLECTOR
42	P	SEP DISPLAY			
43	P	EXT BUSY (L)			
44	S	EXT BUSY (R)			
45	P	ACC (L)	SYS	14	ACC
46	S	ACC (R)			

#	P/S	Name	Module	#	Name	Comments
HIGH LEVEL PROGRAMMING CONNECTIONS						
1	S	A DETECTOR	1D	31	PROGRAMMER CONTROLS	6 WAY
2	S	A-1	1D	29	DETECTED	
3	S	A-32	1D	30	UNDETECTED	
4	S	B AMENDER				6 WAY
5	S	B-1				
6	S	B-32				
7	S	C STANDARD ANALYSER	MS3	47	PROGRAMMER CONTROL PLUG	6 WAY
8	S	C-1	MS3	45	INPUT	
9	S	C-32	MS3	46	PR	
10	S	D AMENDER/STD ANALYSER				6 WAY
11	S	D-1				
12	S	D-32				
13	S	E COLLECTOR	CC	33	PROGRAMMER CONTROL COLLECTOR	6 WAY
14	S	E-1				
15	S	E-32				
16	S	F CFFI/FIFI	FIFI	23	PROGRAMMER CONTROLS	6 WAY
17	S	F-1				
18	S	F-32				
19	S	G FUNCTION ANALYSER 1	FIFI	24	SOFTWARE CODES (T)	6 WAY
20	S	G-1				
21	S	G-32				
22	S	H FUNCTION ANALYSER 2				
23	S	H-1				
24	S	H-32				
25	S	I FUNCTION ANALYSER 3	1D			6 WAY (1)
		I-2		33	LOAD A	
		I-4		34	LOAD B	
		I-8		32	INSERT FOR 6 BIT	
26	S	I-1				
27	S	I-32				
28	S	J FUNCTION ANALYSER 4				
29	S	J-1				
30	S	J-32				

(1) This 6 way cable is formed by three twisted pairs.

#	P/S	Name	Module	#	Name	Comments
HIGH LEVEL PROGRAMMING CONNECTIONS (cont'd)						
31	S	K				6 WAY
32	S	K-1				
33	S	K-2				
34	S	K-4				
35	S	K-8				
36	S	K-16				
37	S	K-32	1D	26	INSERT FOR KEYBOARD	
38	S	L				6 WAY
39	S	L-1				
40	S	L-2				
41	S	L-4				
42	S	L-8				
43	S	L-16				
44	S	L-32				
45	S	M				6 WAY
46	S	M-1				
47	S	M-2				
48	S	M-4				
49	S	M-8				
50	S	M-16				
51	S	M-32				
52	S	N				6 WAY
53	S	N-1				
54	S	N-2				
55	S	N-4				
56	S	N-8				
57	S	N-16				
58	S	N-32				
80	P	O AMENDER				32 WAY
81	P	P STANDARD ANALYSER	MS3	53	SIZE DISTRIBUTION	32 WAY
82	P	Q CLASSIFIER	CC	47	SIZE DISTRIBUTOR	32 WAY
83	P	R FORM SEPARATOR				32 WAY
84	S	S/T VARIABLE FRAME				32 WAY
71	S	U STEP STAGE				
72	S	W CLASS SELECT	CC	34	PROGRAMMER CONTROL CLASSIFIER (L)	
73	S	X EXT DISP CONTROL				

#	P/S	Name	Module	#	Name	Comments
STANDARD REAR CONNECTIONS						
59	P	H TRIG (L)	SYS	29	H TRIG	
60	S	H TRIG (R)	MKI	3	H TRIG (L)	
61	P	PAUSE (L)	FIFI	42	PAUSE (R)	
62	S	PAUSE (R)				
63	P	RESET (L)	SYS	13	RESET	
64	S	RESET (R)				
65	S	AUTO	FIFI	47	AUTO	
66	S	WRITE				
67	P	INT BUSY	FIFI	49	INT BUSY (R)	
68	P	EXT BUSY WHITE	FIFI	52	EXT BUSY (R)	
69	P	EXT BUSY BLACK				
70	S	FOOT SWITCH	TERMINATED			
74	P	HOLD (L)	FIFI	44	HOLD (R)	
75	S	HOLD (R)	FC	17	HOLD (L)	
76	S	COLL HOLD	CC	29	HOLD (L)	
77	P	SLOW CLOCK	SYS	28	SLOW CLOCK	
78	S	CONTROL BUS	TERMINATED			40 WAY
79	P	CALC/COMPUTER	PDP-11		DR11-C	40 WAY

DISPLAY (DPLY)

#	P/S	Name	Module	#	Name	COMMENTS
HIGH LEVEL PROGRAMMING CONNECTIONS						
1	P	LIVE FRAME IN	MS3	29	LIVE FRAME IN (R)	
2	P	BLANK FRAME IN	ID	20	BIG FRAME IN (R)	
3	P	FRAME BRIGHT UP 1	DPLY	4	FRAME BRIGHT UP 2	
4	P	FRAME BRIGHT UP 2	DPLY	3	FRAME BRIGHT UP 1	
5	S	FRAME BRIGHT UP 3	DPLY	6	FRAME BRIGHT UP 4	
6	S	FRAME BRIGHT UP 4	DPLY	5	FRAME BRIGHT UP 3	
STANDARD REAR CONNECTIONS						
7	P	DETECTED DISPLAY	ID	40	DETECTED DISPLAY (R)	
8	P	COMPUTED DISPLAY	MS3	52	ANALYSER DISPLAY (R)	
9	P	NUMERICAL DISPLAY	SYS	11	NUMERICAL DISPLAY	
10	P	SCALE 1 DISPLAY	VFS	17	SCALE DISPLAY	
11	P	SCALE 2 DISPLAY				
12	S	DISPLAY VIDEO	ID	43	DISPLAY VIDEO	BNC
13	S	COMPOSITE VIDEO TO EXTERNAL DISPLAY				BNC
14	P	BLANK +10	SYS	27	BLANK +10	
15	P	SYNC +16	SYS	22	SYNC +16	
16	P	ERASE	SYS	23	ERASE	

FUNCTION COMPUTER (FC)

#	P/S	Name	Module	#	Name	Comments
HIGH LEVEL PROGRAMMING CONNECTIONS						
1	P	VOLUME IN (L)				
	S	VOLUME IN (R)				
2	S	FUNCTION OUT	CC	1	CLASSIFIER FUNCTION IN (L)	20 WAY
7	P	INPUT NORMAL (L)	MS3	7	SIZING IN NORMAL (R)	
8	S	INPUT NORMAL (R)	FIFI	6	DET IN (T)	
9	P	MODIFIED +17 (L)	MS3	9	SIZING IN MOD (R)	
10	S	MODIFIED +17 (R)	TERMINATED			
CONTROL INTERFACE CONNECTIONS						
6	S	PROGRAMMER CONTROL	FIFI	24	SOFTWARE CODES (B)	
STANDARD REAR CONNECTIONS						
3	P	EXTERNAL DRIVE (L)	FIFI	32	EXTERNAL DRIVE	20 WAY
	S	EXTERNAL DRIVE (R)				
4	S	FUNCTION CONTROL (L)	FIFI	30	FUNCTION CONTROL	20 WAY
5	P	FUNCTION CONTROL (R)	MS3	48	FUNCTION CONTROL	20 WAY
11	P	CLOCK (L)	VFS	14	CLOCK (R)	
12	S	CLOCK (R)	TERMINATED			
13	P	COMPUTER DISPLAY (L)	CC	37	COMPUTER DISPLAY (R)	
14	S	COMPUTER DISPLAY (R)	MS3	51	ANALYSER DISPLAY (L)	
15	P	EXT BUSY (L)				
16	S	EXT BUSY (R)				
17	P	HOLD (L)	CIF		HOLD (R)	
18	S	HOLD (R)				

FIELD/IMAGE/FEATURE INTERFACE (FIFI)

#	P/S	Name	Module	#	Name	Comments
HIGH LEVEL PROGRAMMING CONNECTIONS						
	S	MEASUREMENT	FIFI		INCREMENT (L)	FLYING LEAD
	P	INCREMENT (L)	FIFI		MEASUREMENT	
1	S	INCREMENT (R)				
2	P	BIG FRAME IN (L)	VFS	1	BIG FRAME OUT	
3	S	BIG FRAME IN (R)	MK1	5	FRAME 1 (L)	
4	P	FIELD DATA IN (T)	CC	24	SELECTED	
5	S	FIELD DATA IN (B)	SYS	1	DATA IN	
6	P	DET IN (T)	FC	8	INPUT NORMAL (R)	
7	S	DET IN (B)	TERMINATED			
8	P	FRAME IN (T)	VFS	18	VARIABLE FRAME OUT	
9	S	FRAME IN (B)	MS3	29	LIVE FRAME IN (L)	
10	P	IMAGE DIGITISED IN (T)	ID	25	DIGITISED VIDEO	20 WAY
11	S	IMAGE DIGITISED IN (B)				20 WAY
12	P	FEATURE FUNCTION IN (T)	CC	8	COLLECTOR FUNCTION 1 IN (R)	20 WAY
13	S	FEATURE FUNCTION IN (B)				20 WAY
14		TRANSFER MODE	CENTER			SWITCH
CONTROL INTERFACE CONNECTIONS						
23	S	PROGRAMMER CONTROLS	CIF	16	F CFFI/FIFI	6 WAY
24	S	SOFTWARE CODES (T)	CIF	19	G FUNCTION ANALYSER 1	6 WAY
25	S	SOFTWARE CODES (B)	FC	6	PROGRAMMER CONTROL	6 WAY
26	P	SOFTWARE CODES 5 (T)				
27	S	SOFTWARE CODES 5 (B)				
28	P	SOFTWARE CODES 0 (T)				
29	S	SOFTWARE CODES 0 (B)				

FIELD/IMAGE/FEATURE INTERFACE (FIFI)

#	P/S	Name	Module	#	Name	Comments
STANDARD REAR CONNECTIONS						
15	P	COUNT TO COL (L)				
16	S	COUNT TO COL (R)				
17	P	FAIL (L)				
18	S	FAIL (R)				
19	P	COLLECT OUT (L)	CC	22	FUNCTIONS COLLECT OUT	
20	S	COLLECT OUT (R)				
21	P	FINISH FROM COLLECTOR	CC	41	FINISH	
22	S	FIFI GATE OUT	CC	13	COLLECTOR GATE IN 3 (L)	
30	P	FUNCTION CONTROL (T)	FC	4	FUNCTION CONTROL (L)	20 WAY
31	S	FUNCTION CONTROL (B)				20 WAY
32	S	EXTERNAL DRIVE	FC	3	EXTERNAL DRIVE (L)	20 WAY
33	S	DMA INPUT	PDP-11		DR11-B	
34	P	DMA OUTPUT	PDP-11		DR11-B	
35	S	AUTO TO SYST CONT	SYS	18	AUTO	
36	S	FINISH TO MS3	MS3	49	FINISH	
37	P	STORE (L)	MS3	40	STORE (R)	
38	S	STORE (R)				
39	P	BV FRAME (L)	VFS	10	BV FRAME (R)	
40	S	BV FRAME (R)	MK1	1	BV FRAME (L)	
41	P	PAUSE (L)	SYS	17	PAUSE	
42	S	PAUSE (R)	CIF	61	PAUSE (L)	
43	P	HOLD (L)	SYS	15	HOLD	
44	S	HOLD (R)	CIF	74	HOLD (L)	
45	P	CLOCK (L)	CC	28	CLOCK (R)	
46	S	CLOCK (R)	TERMINATED			
47	P	AUTO	SYS	65	AUTO	
48	S	AUTO NO PROG				FLYING LEAD
49	P	INT BUSY (L)				
50	S	INT BUSY (R)	CIF	67	INT BUSY	
51	P	EXT BUSY (L)				
52	S	EXT BUSY (R)	CIF	68	EXT BUSY	
53	S	FOOTSWITCH	TERMINATED			
54	P	COMPUTER DISPLAY (L)				
55	S	COMPUTER DISPLAY (R)	CC	36	COMPUTER DISPLAY (L)	

LIGHT PEN (LP)

#	P/S	Name	Module	#	Name
HIGH LEVEL PROGRAMMING CONNECTIONS					
1	S	BLANK FRAME OUT			
2	S	KEY OUT	MS3	12	KEYS 2 IN (L)
3	P	BIG FRAME IN (L)	SYS	3	STD BIG FRAME OUT
4	S	BIG FRAME IN (R)	LP	5	BLANK FRAME IN (L)
5	P	BLANK FRAME IN (L)	LP	4	BIG FRAME IN (R)
6	S	BLANK FRAME IN (R)	VFS	5	STD BIG FRAME IN (L)
7	P	DETECTED VIDEO IN (L)	ID	1	DETECTED VIDEO OUT SELECTED
8	S	DETECTED VIDEO IN (R)	MS3	1	COINC 1 IN (L)
CONTROL INTERFACE CONNECTIONS					
9	S	AUTO TO SYSTEM CONTROL			
10	S	FOOT SWITCH			
STANDARD REAR CONNECTIONS					
11	P	DETECTED DISPLAY (L)			
12	S	DETECTED DISPLAY (R)	ID	38	DETECTED DISPLAY (L)
13	P	STORE (L)	SYS	24	STORE
14	S	STORE (R)	MS3	39	STORE (L)
15	P	CLOCK (L)	SYS	33	CLOCK (C)
16	S	CLOCK (R)	MS3	35	CLOCK (L)
17	S	FOOT SWITCH IN	TERMINATED		

FRAME SMASHER MK1 (MK1)

#	P/S	Name	Module	#	Name	Comments
HIGH LEVEL PROGRAMMING CONNECTIONS						
5	P	FRAME 1 (L)	FIFI	3	BIG FRAME IN (R)	
6	S	FRAME 1 (R)	MK1	7	FRAME 2 (L)	
7	P	FRAME 2 (L)	MK1	6	FRAME 1 (R)	
8	S	FRAME 2 (R)	1D	19	BIG FRAME IN (L)	
STANDARD REAR CONNECTIONS						
1	P	BV FRAME (L)	FIFI	40	BV FRAME (R)	
2	S	BV FRAME (R)				
3	P	H TRIG (L)	CIF	60	H TRIG (R)	
4	S	H TRIG (R)				
9	S	SMASHER	MK1		ON/OFF	SWITCH
10	S	O/P	1D	10	BLANK FRAME IN	

STANDARD ANALYSER (MS3)

#	P/S	Name	Module	#	Name
HIGH LEVEL PROGRAMMING CONNECTIONS					
1	P	COINC 1 IN (L)	LP	8	DET VIDEO IN (R)
2	S	COINC 1 IN (R)	MS3	6	SIZING IN NORMAL (L)
3	P	COINC 2 IN (L)			
4	S	COINC 2 IN (R)	TERMINATED		
5	S	COINC EXTEND OUT			
6	P	SIZING IN NORMAL (L)	MS3	2	COINC 1 IN (R)
7	S	SIZING IN NORMAL (R)	FC	7	INPUT NORMAL (L)
8	P	SIZING IN MODIFIED (L)	MS3	33	MODIFIED VIDEO OUT VA
9	S	SIZING IN MODIFIED (R)	FC	9	MODIFIED +17
10	S	KEYS OUT	MS3	11	KEYS (1) IN
11	P	KEYS 1 IN	MS3	10	KEYS OUT
12	P	KEYS 2 IN (L)	LP	2	KEY OUT
13	S	KEYS 2 IN (R)			
14	P	KEYS 3 IN (L)			
15	S	KEYS 3 IN (R)			
16	P	GATE 1 IN (L)			
17	S	GATE 1 IN (R)			
18	P	GATE 2 IN			
19	S	COUNT OUT			
20	S	FUNCTIONS VERT INT			
21	S	FUNCTIONS A			
22	S	FUNCTIONS FORK COUNT			
23	S	FUNCTIONS INT			
24	S	FUNCTIONS PERIMETER			
25	S	FUNCTIONS GATED COUNT			
26	P	FUNCTIONS DATA IN	ID	13	DATA OUT SELECTED (R)
27	S	FUNCTIONS SELECTED	CC	23	FUNCTIONS DATA IN
28	P	LIVE FRAME IN (L)	FIFI	9	FRAME IN (B)
29	S	LIVE FRAME IN (R)	DPLY	1	LIVE FRAME IN
30	S	MODIFIED VIDEO OUT P			
31	S	MODIFIED VIDEO OUT VP			
32	S	MODIFIED VIDEO LUT V+P			
33	S	MODIFIED VIDEO OUT VA	MS3	6	SIZING IN MOD (L)
34	S	COUNT TO COLL GATE	CC	9	COLLECTOR GATE IN 1 (L)

#	P/S	Name	Module	#	Name	Comments
CONTROL INTERFACE CONNECTIONS						
47	S	PROGRAMMER CONTROL	CIF	7	C STANDARD ANALYSER	6 WAY
45	P	INPUT	CIF	8	C-1	
46	P	PR	CIF	9	C-32	
53	P	SIZE DISTRIBUTION	CIF	81	P STANDARD ANALYSER	32 WAY
STANDARD REAR CONNECTIONS						
35	P	CLOCK (L)	LP	16	CLOCK (R)	
36	S	CLOCK (R)	CC	27	CLOCK (L)	
37	P	V TRIG (L)	SYS	30	V TRIG	
38	S	V TRIG (R)	VFS	11	V TRIG (L)	
39	P	STORE (L)	LP	14	STORE (R)	
40	S	STORE (R)	FIFI	37	STORE (L)	
41	P	DIVIDE BY 16 (L)	SYS	16	DIVIDE BY 16	
42	S	DIVIDE BY 16 (R)	TERMINATED			
43	P	UNSYNC (L)	SYS	20	UNSYNC	
44	S	UNSYNC (R)				
48	S	FUNCTION CONTROL	FC	5	FUNCTION CONTROL (R)	20 WAY
49	P	FINISH	FIFI	36	FINISH TO MS3	
50	S	FAIL	CC	38	FAIL (L)	
51	P	ANALYSER DISPLAY (L)	FC	14	COMPUTER DISPLAY (R)	
52	S	ANALYSER DISPLAY (R)	DPLY	8	COMPUTED AMENDED/DISPLAY	

SYSTEM CONTROL (SYS)

#	P/S	Name	Module	#	Name
HIGH LEVEL PROGRAMMING CONNECTIONS					
1	P	DATA IN (L)	FIFI	5	DATA IN
2	S	DATA IN (R)	TERMINATED		
3	S	STD BIG FRAME OUT	LP	3	BIG FRAME IN (L)
4	S	STD SMALL FRAME OUT	VFS	7	STD SMALL FRAME IN (L)
CONTROL INTERFACE CONNECTIONS					
	S	PROGRAMMER CONTROLS SELECT ACC	TERMINATED WITH FLYING LEAD		
STANDARD REAR CONNECTIONS					
5	S	LEFT			
	S	READ	TERMINATED WITH FLYING LEAD		
	S	INT	TERMINATED WITH FLYING LEAD		
6	P	OFLO (LEFT)			
7	S	RIGHT			
8	P	OFLO (RIGHT)			
9	P	INPUT BUSY			
10	S	EXT BUSY			
11	S	NUMERICAL DISPLAY	DPLY	9	NUMERICAL DISPLAY
12	S	FOOTSWITCH	TERMINATED		
13	S	RESET	CIF	63	RESET (L)
14	S	ACC	CC	45	ACC (L)
15	S	HOLD	FIFI	43	HOLD
16	S	DIVIDE BY 16	MS3	41	DIVIDE BY 16
17	S	PAUSE	FIFI	41	PAUSE
18	P	AUTO	FIFI	35	AUTO TO SYST CONT
19	S	INTAR			
20	S	UNSYNC	MS3	43	UNSYNC
21	S	SYNC	ID	23	SYNC (L)
22	S	SYNC +16	DPLY	15	SYNC +16
23	S	ERASE	DPLY	16	ERASE
24	S	STORE	LP	13	STORE (L)
25	S	BV FRAME	ID	21	BV FRAME (L)
26	S	PK WHITE	ID	27	PK WHITE (L)
27	S	BLANK +10	DPLY	14	BLANK +10
28	S	SLOW CLOCK	CIF	77	SLOW CLOCK
29	S	H TRIG	CIF	59	H TRIG (L)
30	S	V TRIG	MS3	37	V TRIG (L)

#	P/S	Name	Module	#	Name	Comments
STANDARD REAR CONNECTIONS (cont'd)						
31	S	LINE				
32	S	CLOCK (L)	1D	35	CLOCK (L)	
33	S	CLOCK (C)	LP	15	CLOCK (L)	
34	S	CLOCK (R)	VFS	13	CLOCK (L)	
35	S	SCANNER VIDEO (L)	1D	41	SCANNER VIDEO	BNC
36	S	SCANNER VIDEO (R)				BNC
	S	SCANNER	PLUMBICON SCANNER			32 WAY
		VIDICON/PLUMBICON	PLUMBICON			SWITCH
	P	CO-ORDINATES				32 WAY
	P	MULTIPLE ACCUMULATORS				32 WAY

VARIABLE FRAME AND SCALE (VFS)

#	P/S	Name	Module	#	Name
HIGH LEVEL PROGRAMMING CONNECTIONS					
1	S	BIG FRAME OUT	FIFI	2	BIG FRAME IN (L)
2	S	SMALL FRAME OUT			
18	S	VARIABLE FRAME OUT	FIFI	8	FRAME IN (T)
3	P	STD FRAME IN (L)	VFS	8	STD SMALL FRAME IN (R)
4	S	STD FRAME IN (R)	TERMINATED		
5	P	STD BIG FRAME IN (L)	LP	6	BLANK FRAME IN (R)
6	S	STD BIG FRAME IN (R)	TERMINATED		
7	P	STD SMALL FRAME IN (L)	SYS	4	STD SMALL FRAME OUT
8	S	STD SMALL FRAME IN (R)	VFS	3	STD FRAME IN (L)
STANDARD REAR CONNECTIONS					
9	P	BV FRAME (L)	ID	22	BV FRAME (R)
10	S	BV FRAME (R)	FIFI	39	BV FRAME (L)
11	P	V TRIG (L)	MS3	38	V TRIG (R)
12	S	V TRIG (R)	CC	25	V TRIG (L)
13	P	CLOCK (L)	SYS	34	CLOCK(R)
14	S	CLOCK (R)	FC	11	CLOCK (L)
15	P	SYNC (L)	ID	24	SYNC (R)
16	S	SYNC (R)			
17	S	SCALE DISPLAY	DPLY	10	SCALE 1 DISPLAY

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